ISSN 0377-9335

ENTOMON

Vol. 16 September 1991 No. 3

CONTENTS

Page

Seasonal variation in the onset of egg laying in a primitively eusocial wasp: implications for the evolution of sociality: RAGHAVENDRA GADAGKAR, SEETHA BHAGAVAN, RASHMI MALPE and C. VINUTHA..... 167

Ovipositional responses of vector mosquitoes to the IGR treated water: V. VASUKI... 175

Taxonomic studies on *Aphelinus* (Hymenoptera: Aphelinidae). 3. Notes on *A. japonicus* and *A. howardii* Ashmead: MOHAMMAD HAYAT..... 179

Taxonomic studies on *Aphelinus* (Hymenotpera: Aphelinidae). 4. A new and three known species from Nepal: MOHAMMAD HAYAT 183

Further studies on the Eriophyid fauna (Eriophyoidea : Acari) of Tamil Nadu: M. MOHANASUNDARAM 187

An energy budget of larval stages of *Dicranogmthus nebulosus* Redt. (Coleoptera: Attelabidae): B. R. KAUSHAL and SHAMILA KALIA 193

Growth, fecundity and hatchability of eggs of *Bombyx mori* L. in relation to rearing space: N. ROYCHOUDHURY, D. C. PAUL and G. SUBBA RAO..... 203

Influence of abiotic factors on larval duration and cocoon yield of silkworm, *Bombyx mori* L. – a search for suitable rearing house : SANTOSH K. GANGWAR and P. SOMASUNDARAM 209

(Continued on cover page 4)

ASSOCIATION FOR
ADVANCEMENT OF ENTOMOLOGY
DEPARTMENT OF ZOOLOGY, UNIVERSITY OF KERALA
KARIAVATTOM, TRIVANDRUM, INDIA 695581

ENTOMON

Entomon is a quarterly journal of the Association for Advancement of Entomology issued in March, June, September and December, devoted to publication of research work on various aspects of insects and other land arthropods.

Address MS and all editorial correspondence to Managing Editor, *Entomon*, Department of Zoology, University of Kerala, Kariavattom, Trivandrum, India 695 581.

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Annual Subscription for institutions:	Rs. 150/- (in India);	$ 50 (abroad, air mail)
" " individuals:	Rs. 50/-	$ 20 (" sea mail)

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Entomon 1991 Vol. 16 No. 3 pp. 167 to 174

SEASONAL VARIATION IN THE ONSET OF EGG LAYING IN A PRIMITIVELY EUSOCIAL WASP: IMPLICATIONS FOR THE EVOLUTION OF SOCIALITY

RAGHAVENDRA GADAGKAR, SEETHA BHAGAVAN, RASHMI MALPE & C. VINUTHA
Centre for Ecological Sciences, Indian Institute of Science,
Bangalore, India 560 012

(*Received* 12 *August* 1990)

When freshly eclosed females of the primitively eusocial wasp, *Ropalidia marginata* are isolated into individual cages, only about half of them build nests and lay eggs and those that do so take a long and variable amount of time (Mean $\pm$ S D $=66 \pm 37$ days) before they lay their first egg. Part of the reason for this delay is because, when kept in isolation, no wasp begins to lay eggs during a period of approximately 82 days from mid - October to early January. Wasps maintained at a constant temperature of $26 \pm 1°C$ however initiate egg laying throughout the year, suggesting that the low temperatures during mid - October to early January may be at least one factor that makes this period unfavourable for wasps maintained at room temperature. Egg laying continues more or less normally throughout October—January however, in all natural and laboratory colonies studied. Natural colonies of *R. marginata* are initiated throughout the year and often by groups of females. Huddling together is a striking feature of the wasps especially on cold mornings. We therefore suggest that the isolated animals in our experiment are unable to lay eggs during the coldest part of the year because of their inability to huddle together, share metabolic heat and perform "co-operative thermoregulation". Such "co-operative thermoregulation" may thus be another factor that facilitates the evolution of sociality.

(*Key words:* social wasp, *Ropalidia marginata*, seasonal variation in egg-laying, evolution of sociality, thermoregulation)

INTRODUCTION

In many primitively eusocial wasps and bees that lack morphological caste differentiation, a group of females nest together, of which one individual assumes the role of the queen while the others become workers and usually die without reproducing (WILSON, 1971; MICHENER, 1974; ROSS & MATTHEWS, 1990). A question of obvious interest is whether differentiation into queens and workers takes place entirely in the adult stage or whether there are any pre-imaginal effects that influence such differentiation. In an attempt to answer this question using the primitively eusocial wasp *Ropalidia marginata* (Lep.) (Hymenoptera : Vespidae), a large number of wasps were isolated into individual cages at eclosion, and thus rescued from any possible suppression of egg laying by conspecifics. A clear pre-imaginal caste bias was found because only about half of the 299 animals so tested built nests and laid eggs while the others died without doing so (GADAGKAR *et al.*, 1988, 1990). An intriguing observation in these experiments is that the time taken by the egg-layers to initiate nests and start laying eggs is often very long and variable.

Here we present results which suggest that part of the reason for the delay in the initiation of egg laying is that low temperatures in the months of November and December are not conducive to the initiation of egg laying by isolated females.

MATERIALS AND METHODS

For all experiments described in this paper, as for those described in the two earlier papers (GADAGKAR *et al.*, 1988, 1990), we have used freshly eclosed females of the primitively eusocial wasp, *R. marginata* whose biology and social organization are described elsewhere (GADAGKAR, 1990 a; GADAGKAR *et al.*, 1982; GADAGKAR & JOSHI, 1983). Naturally occurring nests were collected from around Bangalore (13° 00′ N and 77° 32′ E), cleared of adults and maintained in the laboratory. Females ecolosing from these nests were tested for their ability to lay eggs by isolating them into individual 22 × 11 × 11 cm ventilated plastic jars. Each animal was provided with a piece of soft wood as a source of building material and an *ad libitum* diet of final instar *Corcyra cephalonica* (Staint.) (Lepidoptera : Pyralidae) larvae honey and tap-water from the same source. All animals were observed for signs of nest building and egg laying every day. One set of animals was maintained in a well ventilated room and allowed to experience natural variations in temperature and light-dark cycle. The daily minimum and maximum temperature were however recorded. The other set of animals was maintained at a constant temperature of 26±1°C in an incubator. Since our main interest was to detect the ability or the lack of it, of the animals to develop their ovaries and lay eggs, the wasps were killed on the day they laid their first eggs. Our experimental procedures are described in more detail by GADAGKAR *et al.* (1988).

RESULTS

Time taken to initiate egg laying

A total of 299 female wasps were tested for their ability to initiate nests and lay eggs in experiments conducted at room temperature (GADAGKAR *et al.*, 1988, 1990). Of these, 150 wasps built nests and laid eggs. The time taken by these wasps to start laying eggs ranged from 14 to 218 days after eclosion. The distribution of these "waiting times" which has a mean of 66 days, a standard deviation of 37 days, and a median of 62 days is shown in Fig. 1.

Seasonal variation in the onset of egg laying:

Why do some wasps take so long to start laying eggs? In an attempt to answer this question, we have examined the variation in the number of wasps that start laying eggs in each month. This brings out the rather unexpected result that no animal started laying eggs in the months of November and December although large number of wasps were alive during these months (Fig. 2). Over the 5 winters that these experiments were conducted, no egg layings were seen between 18th October and 9th January. It therefore appears that at least part of the reason for the delayed initiation of egg laying is that there is a fairly long unfavourable period of about 82 days during which the wasps do not start laying eggs.

Surely there would be some inherent delay in the onset of egg laying caused by the time required to attain reproductive maturity, but the long unfavourable period during winter could add to the delay observed. For instance, some animals may otherwise be ready to lay eggs during November and December but may have to wait till the unfavourable period passes before they can start laying eggs. This conjecture is supported by the distribution of "waiting times" shown separately for animals that lay eggs in the same year as their eclosion (without getting caught in winter) and those that wait for winter to pass before laying eggs (Fig. 3). The

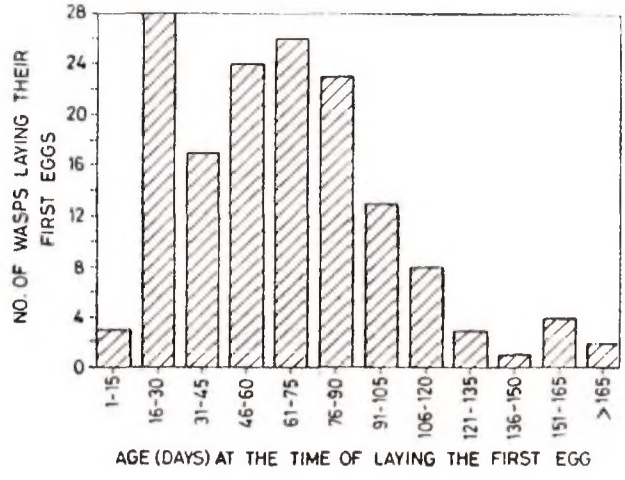

Fig. 1. Frequency distribution of wasps in different age classes at the time of laying their first eggs. (Mean = 66, S. D. = 37 and Median = 62).

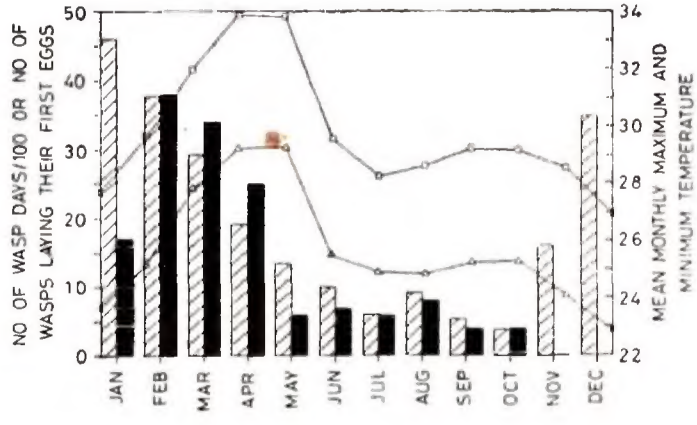

Fig. 2. Number of wasps laying their first eggs in different calendar months of the year (shaded bars). Variation from month to month in this regard should be interpreted in relation to the number of wasps alive during that month from among which animals could start laying eggs. This is shown as the number of wasp days for each month which is computed as the sum of the number of wasps alive during each day in that month (hatched bars). Data are pooled for all 5 years. Notice that no wasp initiated egg laying in the months of November and December although large numbers of them were alive during these months. The mean monthly maximum and minimum temperatures recorded during the experiment and averaged over years for each month are also shown.

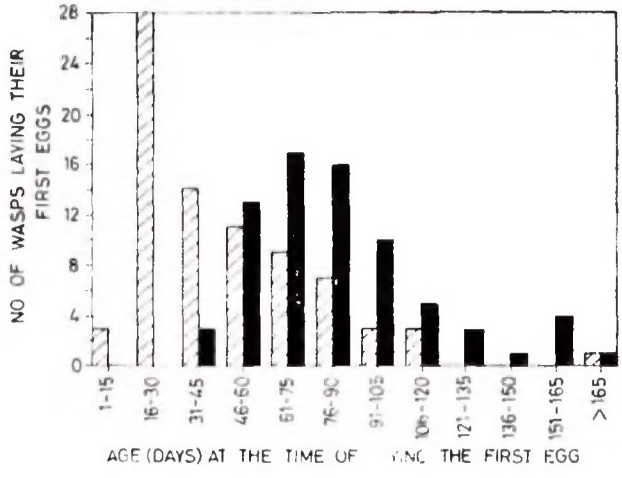

Fig. 3. Frequency distribution of wasps in different age classes at the time of laying their first eggs are shown separately for animals that initiate egg laying in the same year as their eclosion (without getting caught in winter) (hatched bars) (mean=48, S. D. = 31 and Median=40) and for those that wait for winter to pass before laying eggs (shaded bars) (Mean=85, S. D.=33 and Median=79). The two mean are significantly different from each other (Mann–Whitney U test, $p<0.0001$).

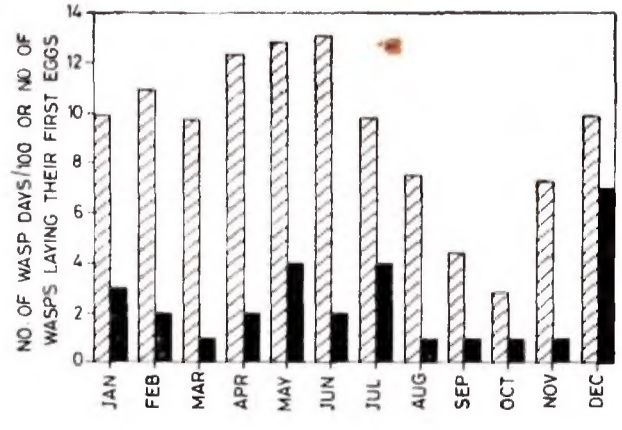

Fig. 4. Number of wasps laying their first eggs in different calendar months of the year (shaded bars) and number of wasp days for each month (defined in legend to Figure 2) (hatched bars) in the experiment conducted at a constant temperature of 26±1°C. Notice that here some animals initiate egg laying in November and December unlike in the experiment at room temperature (Fig. 2).

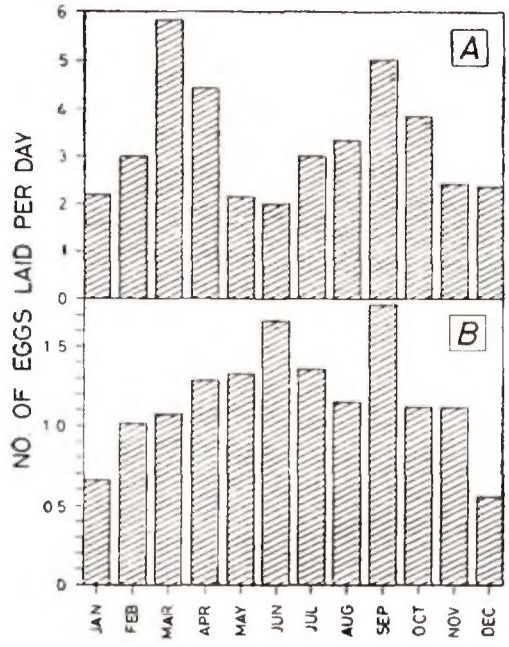

Fig. 5. A: Number of eggs laid per day during different calendar months averaged over four natural colonies which were observed approximately once in two days for about two years. These colonies had 20 or more females during most of the period under observation and a single egg-layer at any given time, B: Number of eggs laid per day during different calendar months averaged over four laboratory colonies which were observed daily for about a year. These colonies had 10 or more females during most of the period under observation and a single egg-layer at any given time.

former distribution (Fig. 3, hatched bars), which has a mean of 48 days represents the inherent delay that may be because of the time taken to attain reproductive maturity. The latter distribution (Fig. 3, shaded bars), which has a mean of 85 days represents the artificially inflated delay due to the unfavourable winter. The resultant mean "waiting time" of 66 days for the total population (Fig. 1) is significantly greater than the inherent mean "waiting time" of 48 days (Fig. 3, hatched bars) (Mann-Whitney U test, $p < 0.0001$). Why should November-December be unfavourable? A particularly striking correlate of seasons is of course temperature. Indeed, mid-October to mid-Janaury is the coldest part of the year in Bangalore as seen from the maximum and minimum temperatures recorded during the experiment (Fig. 2).

Wasps reared at constant temperature

Although many other factors vary with the seasons, a plausible hypothesis is that the period between mid-October and early January is unfavourable because of the low temperature prevailing at this time. To test this hypothesis, we have repeated the experiment at a constant temperature of 26 $\pm$1°C throughout the year in an incubator. The results of this experiment show clearly that the low temperature during November-December must be a major factor in making this period unfavourable. Several animals initiaited egg laying in the

month of December when the wasps were reared at constant temperature (Fig. 4).

Comparison with Natural and Laboratory colonies

The fact that no animal ever started laying eggs in the months of November-December out of the 150 egg-layers in the experiments at room temperature is rather surprising. There is no apparent cessation of egg laying activity in several natural and laboratory colonies that we have observed from time to time (Fig. 5).

DISCUSSION

When female wasps of the primitively eusocial species *R. marginata* are isolated into individual cages at eclosion, only about half of them initiate nests and lay eggs. Among those that do so, there is considerable delay in the time taken to build nests and start laying eggs. At least part of this delay is because a period of about 82 days during late October to early January appears to be unfavourable for the onset of egg laying. But isolated animals initiate nests and lay eggs during November-December when they are kept in an incubator at constant temperature. Although there may be other differences between the conditions experienced by animals kept at room temperature and those in the incubator, temperature is an obvious one. We therefore suspect that the low temperature during mid-October to early January is at least partly responsible for the unfavourableness of this period. Egg laying continues at an appreciable rate however, during November-December in all natural colonies that we have observed. It is true that the animals in our experiment could not raise their body temperature by flying out and basking in the sun as animals in natural colonies can, but we rule out this as a critical factor because egg laying continues more or less normally during November-December in laboratory colonies too. A major difference between the animals in our experiment on the one hand and those in laboratory and natural colonies on the other, is that the former are isolated while the latter are in groups. It is therefore a reasonable hypothesis that the animals in our experiment did not lay eggs during the coldest part of the year because of their inability to huddle together with conspecifics, share metabolic heat and perform what might be called "co-operative thermoregulation".

The final test of this hypothesis must of course come from measurements of body temperature of isolated animals and those in groups at different temperatures. Although such measurements are presently beyond the scope of our laboratory, we have several reasons to believe that the strategy of "co-operative thermoregulation" is available to female *R. marginata* to raise their body temperatures, develop their ovaries and lay eggs during an otherwise unfavourable period. (1) Approximately 70% of the colonies are initiated by groups of foundresses whose number may be as high as 20, thus making "co-operative thermoregulation" possible (GADAGKAR *et al.*, 1982). (2) Nests are initiated throughout the year including the winter months suggesting that initiation of egg laying is possible during the winter months (GADAGKAR *et al.*, 1982; unpublished observations). (3) Both the phenomena of huddling together and the effect of temperature on the behaviour of the wasps are clearly evident during our attempts to collect colonies of *R. marginata* for experimental work. We find that almost all the wasps are huddled together, often behind the nest, in the early hours of the morning (before 6.00 a. m.) when we collect the colonies. The huddling is much more

striking during winter or on otherwise colder mornings, when collecting a colony is relatively easy. During summer months or on otherwise warmer mornings, the wasps are easily disturbed, come to the front of the nest and even fly out and sting us, thus making collection difficult (GADAGKAR *et al.*, unpublished obsevations).

At the heart of most theories attempting to explain the evolution of insect sociality is an asymmetry in the productivities of solitary nesters and joint nesters. Defence against predators and parasites (LIN & MICHENER, 1972; GIBO, 1978; STRASSMANN *et al.*, 1988) and a greater ability to resist nest usurpation by conspecifics (GAMBOA, 1978) and better fitness returns in the face of high adult mortality and long brood-developmental times (QUELLER, 1989; GADAGKAR, 1990 b) are commonly cited reasons for the better performance of multiple-foundress associations as opposed to solitary individuals of wasps and bees. On the basis of the results reported here, we wish to suggest "co-operative thermoregulation" as yet another factor that would favour group nesting. We laso wish to point out that both the above hypotheses we have considered namely, the possibility of wasps raising their body temperature by basking in the sun and of their doing so by "co-operative thermoregulation" have parallels in behavioural mechanisms for thermoregulation known for other insects (CASEY, 1981). Finally, we emphasize that if an advantage of group-living based on "co-operative thermoregulation" can be discerned in Bangalore where the winter minimum temperature rarely goes below 15°-20°C, such an advantage should be substantial at other latitudes where the winters are much colder.

There is yet another difference between the animals in our experiment and those in natural and laboratory colonies. Our data pertaining to natural and laboratory colonies reflect the ability of wasps having already developed their ovaries to continue to lay eggs in November-December (Fig. 5). On the other hand, our data on isolated animals (Fig. 2) reflect the inability of these animals to initiate egg laying in the months of November - December. To the extent that temperature may differentially affect the initiation and continuation of egg laying, this will be a confounding factor in our interpretation. In other words, we do not know at this stage whether isolated animals cannot merely begin to lay eggs in November-December or whether they cannot also continue to lay eggs in November - December in spite of having begun to lay eggs earlier. We hope to distinguish between these two possibilities in future experiments. Whatever the outcome of these expriments, an additional advantage if group life in the form of "co-operative thermoregulation" will remain in at least as far as initiation of egg laying is concerned.

ACKNOWLEDGEMENTS

We thank Mr. K. CHANDRASHEKARA and Mrs. SWARNALATHA CHANDRAN for some of the data in Figure 5 and Dr. A. P. GORE, Dr. V. NANJUNDIAH and Prof. MADHAV GADGIL for helpful discussions. Supported in part by a grant from the Indian National Science Academy, New Delhi (Principal Investigator, RG).

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Entomon 1991 Vol. 16 No. 3 pp. 175 to 178

OVIPOSITIONAL RESPONSES OF VECTOR MOSQUITOES TO THE *IGR*-TREATED WATER

V. VASUKI
Vector Control Research Centre (ICMR)
Pondicherry, India 605 006

(*Received* 30 *June* 1990)

Insect growth regulator (IGR) OMS 3031 treated water elicited high deterrent activity in ovipositing females of *Culex quinquefasciatus*, *Aedes aegypti* and *Anopheles stephensi*. Negative ovipositional responses of the three test species to IGR treated water resulted in OAI values of –0.66, –0.53, -0.35 at 1.0 mg/l and -0.97, -0.85, -0.99 at 5.0 mg/l respectively in the same order. The high degrees of mortality observed in gravid and oviposited females soon after coming in contact with oviposition medium treated with OMS 3031 were found to be significant at doses higher than 1.0mg/l implying the possible contact toxicity of the compound. The death and subsequent drowning of the gravid females and sinking of freshly laid eggs at higher dosages may also be due to the formulation of the IGR tested as shown by the decreased surface tension. IGRs like OMS 3031 can play an important role in suppressing vector population by affecting the oviposition cycle of the vectors, thereby adversely influencing the transmission of the disease pathogen.

(*Key words:* chitin synthesis inhibitor, XRD–473, ovipositional responses, *Culex quinquefasciatus*, *Aedes aegypti*, *Anopheles stephensi*)

INTRODUCTION

Oviposition is an important component of most of mosquito-borne diseases. The substances involved in oviposition site choice by the vector mosquitoes have recently become the focus of interest in the concept of Integrated Vector Management (GRAHAM-BRYCE, 1987). Substances of egg origin and (BRUNO & LAURENCE, 1979), larval origin (KALPAGE & BRUST, 1973), pupal origin (ANDREADIS, 1977) and from other sources (ROCKETT, 1987) have produced highly selective oviposition attractancy against vector mosquitoes. Few insecticides in common use have also exhibited high deterrent activity causing negative ovipositional response (MOORE, 1977).

Insect growth regulators (IGR), an effective group of alternate bioinsecticide, show greater scope in control strategy by affecting the post apolytic stage of the larvae by disrupting either chitin synthesis or metamorphosis resulting in the death of the larvae, pupae and incompletely emerging adults (RETNAKARAN *et al.*, 1985). Besides being interruptors of moulting, IGRs are found to inhibit hatching of eggs of some vector mosquitoes (MIURA *et al.*, 1976). However, information on the ovipositional responses of mosquitoes to IGR treated medium is scanty.

The present study is focused on the ovipositional responses of three species of vector mosquitoes, *Culex quinquefasciatus*, *Aedes aegypti* and *Anopheles stephensi* to IGR treated oviposition medium.

MATERIAL AND METHODS

The Insect Growth Regulator XRD-473 (OMS 3031-Hexaflumuron), belonging to the group of benzoylphenylurea compounds, received as gratis supply from Dow

chemical company, USA, through WHO, was used in this study. Three species of vector mosquitoes were obtained from the cyclic colonies maintained at VCRC. One percent stock solution of XRD-473 was prepared in ethanol and serial dilutions were made thereafter as per the required test concentrations. One ml of the stock solution was added to 199 ml of tap water to give final concentrations of 0.1, 1.0 and 5.0 mg/l. Controls with 1 ml of ethanol and 199 ml of tap water was taken. Both test and control solutions were taken in enamel bowls (14 cm dia) and placed in a mosquito cage ($55 \times 55 \times 55$ cm) containing 100 fully gravid mosquitoes of the test species. Every day the experiment was started at 16 h and the counting of egg rafts/eggs was made at 10 a.m. the next day. The position of the bowls was changed every time and the experiment was repeated four times at 27 ± 2°C and RH 70–80%.

The oviposition Active Index (OAI) (Yih *et al.* 1982) was then calculated using the formula, $OAI = \frac{Nt - NS}{Nt + Ns}$

where Nt is the total number of eggs in test solution and Ns is the total number of eggs in control. This series of compounds were reported to have contact effects on few agricultural pests causing mortality in adults especially ovipositing females (Ascher & Nemny, 1976). Though no appreciable residual toxicity on the treated dry surface could be seen for these species, gravid as well as oviposited females were found dead on the surface of the treated water. Mosquitoes alighted on the treated water surfaces were unable to take off and eventually died. A few which managed to crawl or fly away died later. Hence an attempt was made to employ forced oviposition techniques to compare the mortality rates of the ovipositing females of the test species in response to contact of mosquitoes in test solutions with that in tap water (control). In this experiment, one bowl with 200 ml of the test solution at the desired concentration and another with tap water and ethanol (control) were kept separately in two mosquito cages. Observations on the mortality of gravid and oviposited females were made after 16–20 h.

Table 1. Oviposition responses and contact toxicity to IGR treated water for *Cx. quinquefasciatus* *Ae. aegypti* and *An. stephensi*.

Dosage treated (mg/l)	Species								
	Cx. quinquefasciatus			*Ae. aegypti*			*An. stephensi*		
	OAI	A	B	OAI	A	B	OAI	A	B
0.1	–0.29	2.75*	10.00	–0.47	4.25	7.00	–0.16	7.50	13.20
1.0	–0.66	29.70	16.20	–0.53	25.00	50.70	–0.35	18.50	28.20
5.0	–0.97	61.50	0.00	–0.85	70.70	18.2	–0.99	89.70	0.00

* — Not significant ($P > 0.05$).
OAI — Oviposition active index.
A — Percentage mortality of gravid females.
B — Percentage mortality of oviposited females.

Since the eggs laid and the dead gravid females in the test solutions were found sunk at the bottom of the bowl, the possible role of surface tension of treated waters at various concentrations of formulated and technical material of OMS 3031 was also determined by using the method described by MURUGAIYAN *et al.* (1984).

Analysis of variance (ANOVA) was performed on the percentage mortality to determine significant ($P<0.05$) treatment differences. Before analysis the percentage data was transformed (Arcsine $\sqrt{p}$) to normalize variance and make them homogenous (SOKAL & ROHLF, 1981).

RESULTS AND DISCUSSION

The ovipositional responses of the gravid females of the three vector mosquito species are presented in Table 1. The OAI values revealed that this IGR compound has repelling activity at higher dosages. However, at 5.0 mg/l all the three species exhibited remarkable negative response resulting in failure of oviposition or oviposition of very few eggs.

Even though comparison of OAI values indicates that the IGR compound elicits repelling activity, it is quite possible that this IGR acts more as an oviposition deterrent inhibiting oviposition at higher dosages in the ovipositing medium than as a oviposition repellent that causes insects to make oriented movements away from the source as proposed by DETHIER *et al.* (1960).

The oviposition deterrent activity exhibited by this IGR is relatively higher when compared to few other insecticides like OP compounds and synthetic pyrethroids (MOORE, 1977; VERMA, 1986). However, another synthetic IGR methoprene has been reported (CARROLL, 1979) to elicit increased oviposition by *Ae. aegypti* in contrast to the present observation.

The mortality rates of the gravid and oviposited females of three species in response to contact with treated water are also given in Table 1. The results show that the mortality of both the gravid and oviposited females display significant ($P < 0.05$) variation among three species. The death of the gravid females and oviposited females on the treated water surface was found to be significantly ($P<0.05$) more at higher dosages. However, at 5.0 mg/l no mortality of oviposited females was observed, since the gravid females whichever attempted to oviposit were found dead even before they could lay eggs.

High degrees of mortality observed in gravid females and ovipositing females on contact with the treated water surface imply the possible contact toxicity of the compound received through the specific sensitive parts of the mosquitoes that help them in oviposition.

Drowning of the gravid females of the three test species and the sinking of freshly oviposited eggs of *Cx quinquefasciatus* were observed at higher dosages. This may be due to lowering of surface tension by the EC formulation of OMS 3031 containing considerable amount of emulsifiers (PAUL BECHER, 1973). This is evidenced by the fact when formulation of OMS 3031 was used, the effect was comparatively higher than that of technical grade material (Fig. 1).

This study infers the importance of IGRs with deterrent activity in the transmission of mosquito-borne diseases. In addition to inhibition of adult emergence achieved by employing IGRs in control operations, mosquitoes can be deterred from the treated breeding and ovipositing

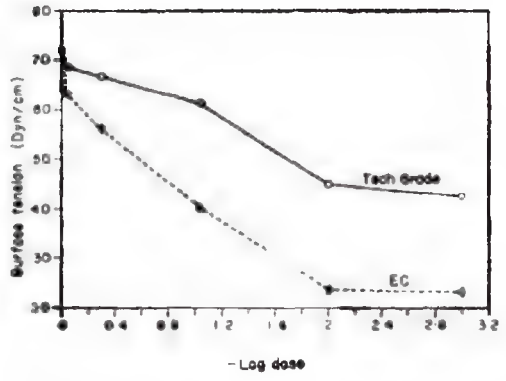

Fig. 1. Range of values of surface tensions found in technical grade and EC formulation of OMS 3031.

sites affecting the completion of the oviposition cycle, thereby disrupting the transmission of the disease pathogen.

ACKNOWLEDGEMENTS

Author is gateful to the Director, VCRC, for providing all facilities and Dr. P. K. Das, Deputy Director, for constant encouragement and guidance. The author also acknowledges the help offered by Mr. A. Manoharan, Statistical Assistant and the technical staff of Insecticides Section. Thanks are due to WHO for the gratis supply of OMS 3031.

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Entomon 1991 Vol. 16 No. 3 pp. 179 to 181

TAXONOMIC STUDIES ON *APHELINUS* (HYMENOPTERA : APHELINIDAE). III. NOTES ON *A. JAPONICUS* ASHMEAD AND *A. HOWARDII* ASHMEAD

MOHAMMAD HAYAT
Department of Zoology, Aligarh Muslim University,
Aligarh. India 202 002

(*Received* 23 *September* 1990)

The little known species of *Aphelinus* from Japan, *A. japonicus* Ashmead is redescribed. *A. howardii* Ashmead, described from Grenada, is transferred to *Coccophagus* as a new combination.

(*Key words:* Aphelinidae, *Aphelinus*, taxonomy of two species)

The present paper on *Aphelinus* is the third in the series, and deals with the systematic position of two little known species described by Ashmead (1900, 1904), one from Grenada and the second from Japan.

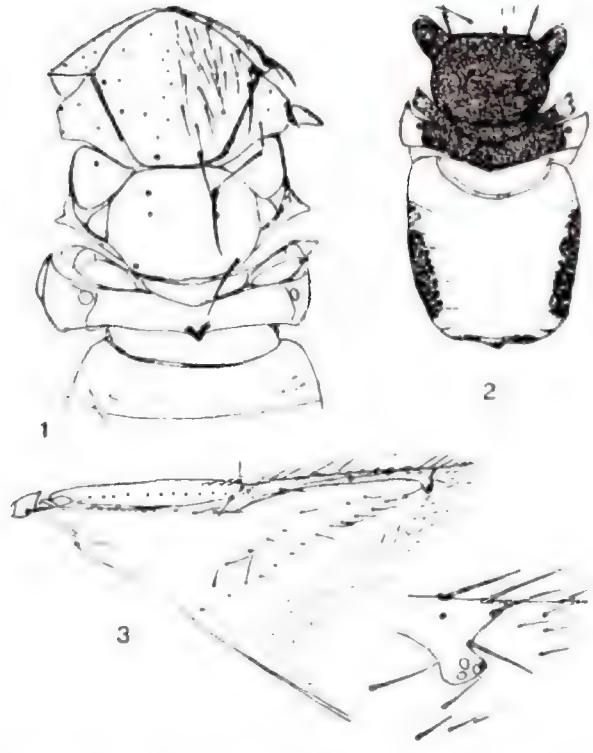
A. japonicus was described from two specimens collected by A. Koebele in Atami, Japan. This species has not since been recorded and its identity has remained largely unknown. It is redescribed and comments on its systematic position are made. *A. howardii* was described from a male from Grenada. This species is here transferred to *Coccophagus* (comb. nov.).
Aphelinus japonicus Ashmead (Figs. 1–3)
Aphelinus japonicus Ashmead, 1904: 161. Female type. Japan, Atami (U. S. National Museum, Washington D. C.) examined.

Redescription:

Female:– Length, 0.95 mm. Head golden to light orange yellow, face and malar space pale yellow; thoracic venter and sides pale yellow, mesoscutum golden yellow with slight brown suffusions anteriorly; axillae dark brown; scutellum, metanotum except brownish sides, and propodeum except yellow sides, black, slightly shiny; petiole and gaster yellow, but paler than mid-lobe with faint brown suffusions, and with narrow, dark brown to black and slightly shiny band on each side on terga II–V, these bands extend somewhat on to sides and venter. Antennae white to pale yellow. Wings hyaline. Legs including coxae white to pale yellow.

Head: frontovertex, at level of lateral ocelli, apparently not wider than dorsal eye width and at least a little longer than wide; setae on frontovertex long and white, each seta about 1.5× as long as the major diameter of a lateral ocellus except a pair on vertico-occipital margin which is 2.5× as long as the major diameter of a lateral ocellus; eyes densely setose, the setae pale; ocelli with apical angle obtuse, lateral ocelli less than 0.5 their major diameter away from eye margins.

Antenna: scape cylindrical, longer than clava (14:11.5); and nearly 6× as long as wide; pedicel slightly more than 1.5× as long as wide; F1 and F2 transverse, both combined about 0.5 of F3, the latter about a quarter longer than wide; clava slightly less than 4× as long as wide or nearly 3× as long as F3.



Figs. 1–3. *Aphelinus japonicus* Ashmead: female: 1, thoracic dorsum, setae on left half omitted, from slide; 2, part of thorax and gaster, from carded specimen before it was mounted on a slide; 3, part of fore-wing with distal veins enlarged and shown separately, setae on ventral surface of coastal cell shown as dots and detached setae by broken lines.

Thorax: after clearing and mounting on a slide, as in Fig. 1; setae white; mid-lobe, axillae and scutellum with fine hexagonal cells, rather prominent on scutellum; middle area of metanotum and of propodeum with fine reticulations; propodeum with a distinct median process as in other species of the genus.

Wings: fore-wing (Fig. 3) a little over 2× as long as wide (69: 32) with the venation more than 0.5 the length of the wing (40:69); costal cell slightly longer than marginal vein (20:19), with a line of setae on ventral surface; linea calva open posteriorly and proximally limited by two lines of setae; marginal fringe about one-fifteenth of wing width. Hind-wing slightly more than 3.5× as long as wide (57 : 15); veins more than 0.5 length of wing (36 : 57) ; disc except below submarginal vein, densely setose; marginal fringe about one-fifth of wing width.

Legs: middle tibia 3.66× as long as middle basitarsus; spur slightly longer than basitarasus; tarsal segment II about two-thirds the length of I (=basitarsus), segments III-V each not longer than 0.5 fo I.

Gaster: petiole plus gaster slightly shorter than thorax (the ratio was 7:9 before mounting the specimen on a slide), and only slightly longer than wide, of uniform width, with the last tergum projecting as a triangular plate from middle of apex; hypopygium (in carded specimen, before mounting it on a slide) reaching

about four-fifths the length of gaster; ovipositor short, extending from about the third segment, and not exserted at apex. (Relative lengths: ovipositor, 8; third valvula, 2; mid-tibia, 11; mid-basitarsus, 3).

Male: Unknown.

Host: Unknown.

Material examined: Type female: U. S. N. M. Type No. 7203. Japan, Atami, coll, Koebele. The specimen was on a card. It is cleared, partly dissected and mounted on a single slide.

Comments: Aphelinus japonicus differs from all the known species of the genus by the partly dark colour of the thorax, the numerous setae mid-lobe not arranged in a symmetry, the short ovipositor, and the hypopygium (when the specimen was on card) not reaching to the apex of the gaster. This last mentioned character may not be very reliable in this species as only a single specimen was available and the condition of the specimen was such that some distorsion in the apical region of the gaster can not be ruled out. I have, therefore, considered it better to retain the species in *Aphelinus*. In *Aphelinus*, it can not be placed in the three subgenera recognized by Hayat (1990) on the basis of the above mentioned characters. Therefore, it is here regarded as a species of a separate group, *japonicus*-group. The correct systematic position of this species can, however, be decided only when fresh material becomes available.

Coccophagus howardii (Ashmead) comb. nov.

Aphelinus howardii Ashmead, 1900 : 264. Male type. Grenada. (Natural History Museum, London) examined. Preoccupied in *Aphelinus* by *A. howardii* Dalla Torre, 1898 : 221.

Aphelinus ashmeadi Gahan, 1924: 11. Replacement name for *howardii* Ashmead. *SYN. NOV.*

Gahan's (1924) suspicion regarding the placement of *howardii* in *Aphelinus* is confirmed by the examination of the male type. The transfer of *A. howadii* Ashmead to *Coccophagus* makes *C. howrardi* Masi 1907, a junior homonym, but a replacement name for Masi's species is not proposed as that species has generally been considered a synonym of *C. pulchellus* Westwood. Westwood.

ACKNOWLEDGEMENTS

I thank Dr M. E. SCHAUFF, U. S. National Museum, Washington, D. C. for loan of the type specimen of *A. japonicus;* and Dr J. S. NOYES, The Natural History Museum, London, for permission to study the type of *A. howardii* during my recent visit to the NHM. I am also thankful to Prof. MUMTAZ A. KHAN, Chairman, Department of Zoology, for necessary facilities.

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Entomon 1991 Vol. 16 No. 3 pp. 183 to 186

TAXONOMIC STUDIES ON *APHELINUS* (HYMENOPTERA : APHELINIDAE). IV. A NEW AND THREE KNOWN SPECIES FROM NEPAL

MOHAMMAD HAYAT
Department of Zoology, Aligarh Muslim University, Aligarh, India 202002

(*Received* 28 *October* 1990)

***Aphelinus nepalensis*, sp. nov. is described, and three known species of the genus, *asychis*, *gossypii* and *varipes*, are recorded from Nepal.**

(*Key words*: Aphelinidae, *Aphelinus* from Nepal)

In connection with studies on the genus *Aphelinus* Dalman, much material was received from the British Museum (Natural History), London (BMNH; now the Natural History Museum, London). Among this material is an interesting, but undescribed, species represented by several specimens, and a short series of three known species, all from Nepal. The present paper deals with these species. The three known species are apparently new records for Nepal, but as these are otherwise well-known, detail citations are not given here.

1. Aphelinus asychis Walker

Material examined:– NEPAL: Kakani, 2070 m, 1 female, 14–30.

iii. 1984, secondary oak forest, (M. G. Allen (BMNH)

2. Aphelinus gossypii Timberlake

Material examined: NEPAL: Taplejung Distr., Sangu, c. 6200 ft.,

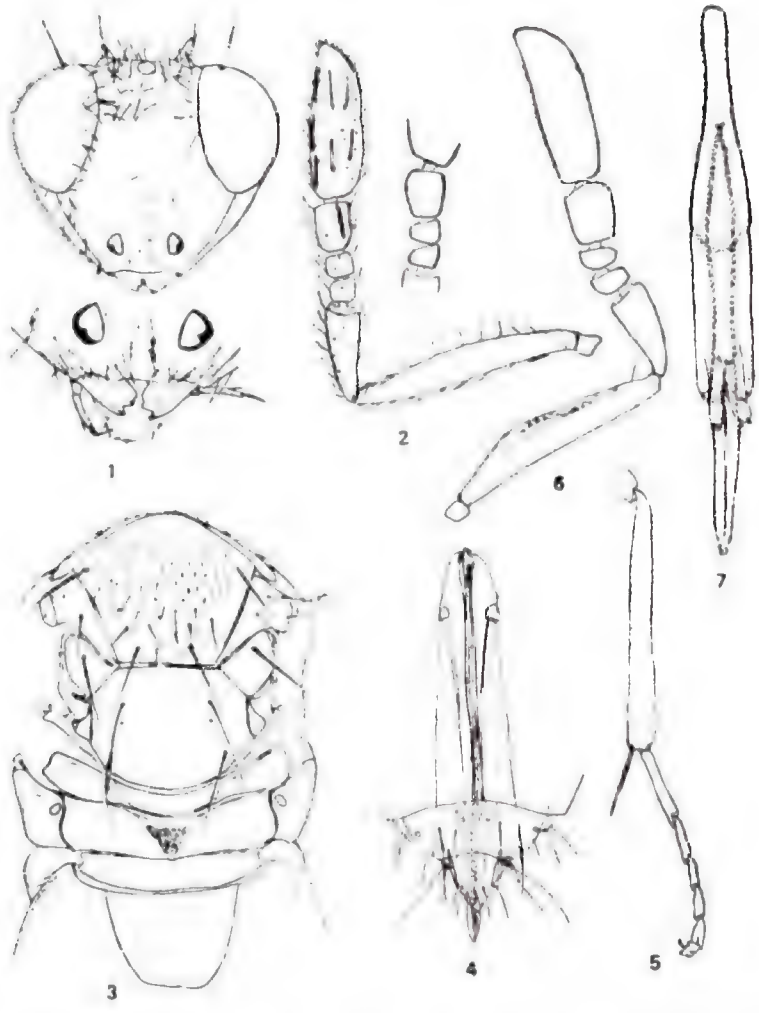
1 female, 16–29. x. 1961, on yellow blooms of cultivated composite, (R. L. Coe) (BMNH)

3. Aphelinus varipes (Foerster)

The identification of the following materials as *varipes* is based on the description provided by Ferriere (1965) and the notes and illustrations given by Graham (1976). I have also compared these specimens with paratypes of *A. maidis* Timberlake, obtained on loan from the U. S. National Museum, Washington D. C. Some relative measurments are given below based on the Nepalese specimens:

Head width, 23, 24.5; frontovertex width at front ocellus, 11, 12, Fore-wing length (width), 51.5 – 58.0 (22.75 – 26.00); number of setae proximad of linea calva, 30 – 41; hind-wing length (width), 44 – 50 (9.75 – 12.00). Distance between propodeal spiracles, 16.0 – 17.5; middle tibia length, 19.5 – 20.5; middle basitarsus length, 5.5 – 6.0; hind-tibia length, 20 – 23; ovipositor (=second valvifer plus third valvula) length, 28.5 – 32. 5; third valvula length, 8.50 – 9.75.

A single female paratype of *maidis* has the ovipositor length, 23.25; third valvula length, 7.25; middle tibia length, 16.5; and hind-tibia length, 19.



Figs. 1–7. *Aphelinus nepalensis*, sp. nov., female except 6 and 7: 1, head front view with facial region enlarged; 2, antenna, flagellum slightly titled, and funicle from a second antenna; 3, thorax, petiole and T1, dorsal; 4, ovipositor with apical gastral terga; 5, middle tibia and tarsus, setae omitted and drawn on the same scale as Fig. 4; 6 antenna, male, setae omitted; 7, male genitalia.
Fig. 8. *Aphelinus nepalensis*, sp. nov., female, part of fore-wing with distal veins enlarged and shown separately, setae on ventral surface of costal cell shown as dots.

Material examined:– NEPAL:

Phulchoki, 2600 m, 8 females, x. 1983, (Smetana); Kakani, 2070 m, 1 female, ix. 1983 (M. G. Allen) (BMNH).

4. Aphelinus nepalensis, sp. nov. (Figs. 1–8).

Female Length, 1.20– 1.63mm (Holotype, 1.63 mm).

Frontovertex and face yellow to yellow brown: occiput above foramen with a distinct brown to dark brown cross-band connecting eyes, sides of occiput and malar space posterior to malar sulcus, yellow brown to brown; thoracic dorsum including propodeum, and sides, dark brown to nearly black and shiny, occasionally the pronotum on sides

or except collar, pleura completely or in lower half yellow; side lobes sometimes either with a yellow brown area on the expanded part or nearly completely brown; petiole dark brown to black; venter of thorax and gaster yellow to yellow brown; dorsum of gaster with a wedge-shaped spot on each side at base (tergum I or I plus part of II) and terga V-VII yellow, tergum I at meson and terga II-IV dark brown to nearly black, the dark colour extends laterally as narrow bands; ovipositor sheaths yellow with tip pale brown. Antennae yellow, occasionally yellow brown. Fore-wing (Fig. 8) with a distinct triangular infuscation. Legs including coxae yellow; hind-tibiae infuscate brown to dark brown; other tibiae occasionally washed with brown; hind-basitarsus sometimes yellow brown.

Setae on frontovertex, thoracic dorsum and gaster dark brown; eyes densely setose, each seta longer than an ommatidium.

Head, dorsal, transverse, at least nearly 3× as wide as long (38.5 : 13; 33:9) (in specimens with frontovertex somewhat shrunken, head nearly 4× as wide as long); frontovertex, at level of front ocellus, distinctly broader than one-third of head width (12.5–16: 33–39); ocellar triangle with apical angle obtuse, lateral ocelli separated from eye margins by slightly less than one diameter of an ocellus and from occipital margin by a distance equal to half or slightly less than half the diameter of an ocellus; head, in front view (Fig. 1), a fifth broader than high (31.5 : 25.5) with malar space nearly flat and strongly narrowed to mouth; frontovertex and face with setae as shown in Fig. 1. Antenna (Fig. 2) with scape long and cylindrical, at least slightly longer than width of frontovertex (14.5 – 16.0 : 12 – 13); F1 and F2 subequal in length, with ventral side slightly longer than dorsal side; F3 quadrate to slightly longer than wide.

Thorax as in Fig. 3; axillae not extending caudad beyond the first pair of scutellar setae; mid-lobe with fine, mostly transversely drawn out cells; scutellum with small hexagonal cells which are longitudinally drawn out on sides. Wings large; fore-wing slightly more than 2× as long as wide (103 – 110 : 45.5 – 50.0), with the total length considerably more than body length (58 – 71 : 48.5 – 65.0); costal cell large, longer than marginal vein (28.0 – 31.5 : 24.5 – 26.0), with a line of setae on dorsal surface and 2–3 lines of setae on ventral surface; linea calva closed posteriorly by a line of setae, and proximally with several setae in 1–2 complete and 4–5 incomplete lines; basal cell with 1–3 setae (Fig. 8). Hind-wing slightly more than 3× as long as wide (86:26).

Petiole plus gaster only slightly longer or subequal to thorax (24 – 30 : 21 - 30), with the apex pointed and the ovipositor distinctly, though shortly, exserted (Fig. 4). (Relative lengths : ovipositor, 46 – 48); third valvula, 14.5 – 15.0; middle tibia, 29.5 – 32.5; middle basitarsus, 9.25 – 10.50; hind-tibia, 34.00 – 37.75; distance between propodeal spiracles, 26 – 29.)

Male: Similar to female, except for longer F3 (Fig. 6).

Genitalia as in Fig. 7. Relative measurements (lengths): middle tibia, 30; hind-tibia, 33; aedeagus, 27.5; phallobase, 26. Distance between propodeal spiracles, 26.5.

Holotype female, NEPAL: Taplejung Distr., Sangu, c. 6200 ft., xi. 1961 – i. 1962, mixed vegetation by stream in a gully, (R.L. Coe). British Museum East Nepal Expedition 1961–1962. B. M. 1962–177 (BMNH).

Paratypes: 15 females, 1 male: 10 females, 1 male, with the same data as holo-

type. Above Sangu, c. 6800 ft., 1 female, 16.ii.1962, mixed vegetation in a dried-up ravine; between Sangu and Tamrang, c. 5200 ft., 1 female, 22.xi.1961, mixed plants by damp cliff in deep river gorge; 1 female same data except i-ii.1962; above Sangu, c. 6500 ft., 1 female, 17.x – 1.xi.1961, edge of mixed forest; between Sangu and Tamrang, c. 5500 ft., 1 female, i-ii.1962, (BMNH).

Comments: This is the most distinctive species of the genus about which I had indicated earlier (Hayat, 1983: p. 68). It differs from all the described species in the shape and dimensions of the head, longer and narrower antennal scape in both the sexes, axillae not extending caudad beyond the first pair of scutellar setae, large costal cell with 2–3 lines of setae on ventral surface, posteriorly closed linea calva, and distinctive colour of the body and legs.

ACINOWLEDGEMENTS

I am thankful to Dr. J. S. Noyes (BMNH) and Dr M. E. Schauff (USNM), for loan of material for the present study. Thanks are also due to Prof. Mumtaz A. Khan, Chairman of the Department of Zoology, for research facilities.

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Entomon 1991 Vol. 16 No. 3 pp. 187 to 192

FURTHER STUDIES ON THE ERIOPHYID FAUNA (ERIOPHYOIDEA : ACARI) OF TAMIL NADU

M. MOHANASUNDARAM
Department of Agricultural Entomology
Agricultural College and Research Institute, Madurai, India 625104

(*Received* 23 *May* 1990)

The paper presents an account of eight species of eriophyid mites collected from Tamil Nadu, of which three are new to science. They are, *Aculus ocimumae* **sp.nov.,** *Anthocoptes bamboovagrans* **sp. nov.,** *Calacarus channabasavannae* **Lukkundi;** *Calacarus jasmini* **Chakrabarti and Mondal;** *Catarhinus munnarensis* **sp. nov;** *Rhombacus morrisi* **Keifer;** *Tegonotus convolvuli* **(Channabasavanna) and** *Tegonotus mangiferae* **(Keifer).**

(*Key words:* Acari, Eriophyoidea, *Aculus*, *Anthocoptes*, *Calacarus*, *Rhombacus*, *Tegonotus*)

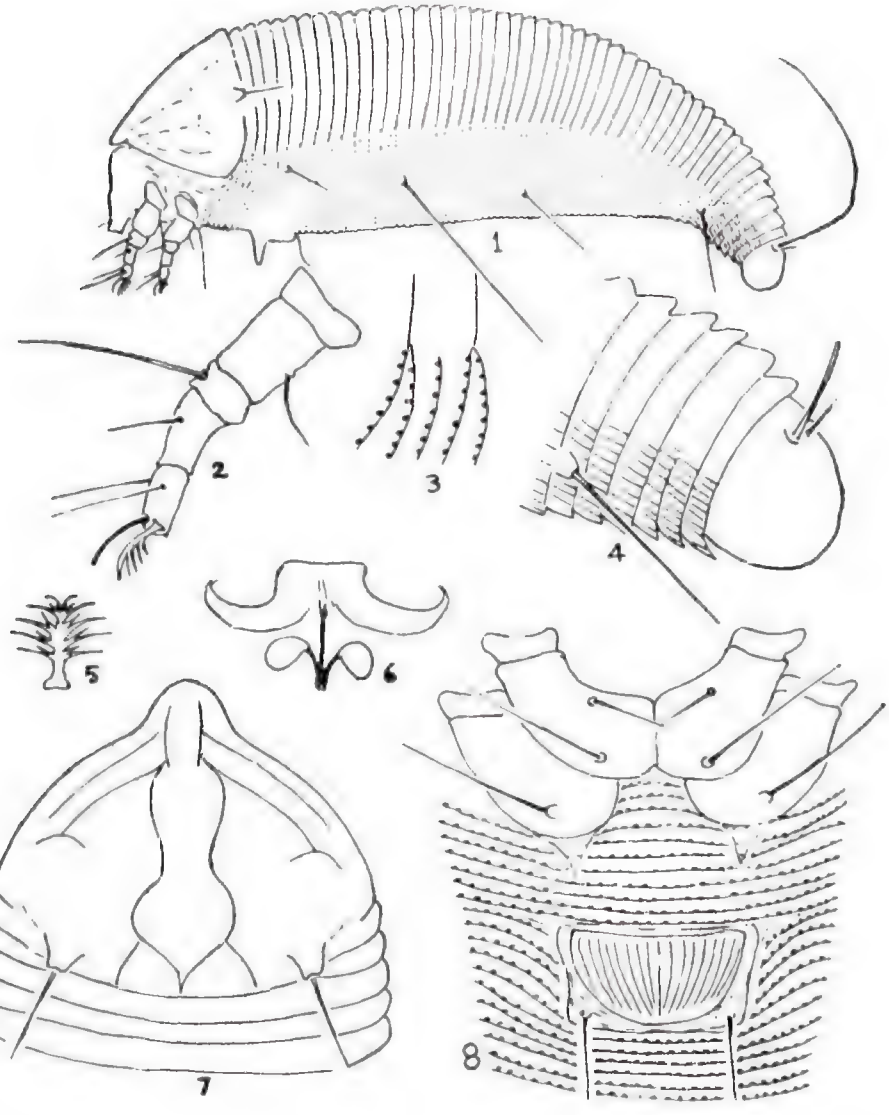
During the survey and study of eriophyid mites in the Southern Districts of Tamil Nadu, three species new to science were encountered. The paper presents eight eriophyids collected and studied during 1989. The new species are adequately sketched and described. In the descriptions all measurements are in μm. The slides containing holotypes and paratypes have been deposited in the collections of the Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore 641 003, India.

1. **Aculus ocimumae** sp. nov. (Figs. 1 to 8)

Female: 230–240 long, 60–70 thick; rostrum 16 long, down curved, antapical seta 5 long; shield 60 wide (58–63), 40 long (39–41), broadly triangular, with a clear pattern; median absent; admedians wavy, branched at the posterior end with the inner branches joining in the middle of the shield margin; first submedian represented in the anterior half of the shield ending as a crescent posteriorly; second submedian forms the border of the shield in the anterior half; sides of the shield fairly clear; dorsal tubercles at rear shield margin, 30 apart, dorsal setae 12 long (11–13) pointing backward and outward. Fore-leg 30 long; tibia 6 long, tibial seta 4 long at basal 1/3; tarsus 6 long, claw 8 long, curved featherclaw simple, 5 rayed; hind-leg 28 long, tibia 4 long, tarsus 6 long; claw 8 long; all usual setation on the legs present. Coxae with all three setiferous tubercles, coxal area smooth. Abdomen with about 45 smooth tergites and about 70 microtuberculate sternites, microtubercles dot like; lateral seta 28 long on ring 8; first ventral seta 45 long on about ring 24, second ventral seta 20 long on about ring 42; third ventral seta 24 long on ring 6 from behind; caudal seta 60 long; accessory seta 4 long, very thin. Female genitalia 22 wide, 14 long; coverflap with 16–18 thin scorings; genital seta 20 long.

Male : Not known

Types: A slide containing holotype (Female) and two paratype slides all with ♀♀; INDIA Tamil Nadu; Madurai, 15. xii. 1989. ex. *Ocimum* sp. (Labiatae), Coll : M. Mohanasundaram (No. 579, TNAU). The yellowish worm like mites are under surface leaf vagrants causing no symptoms.

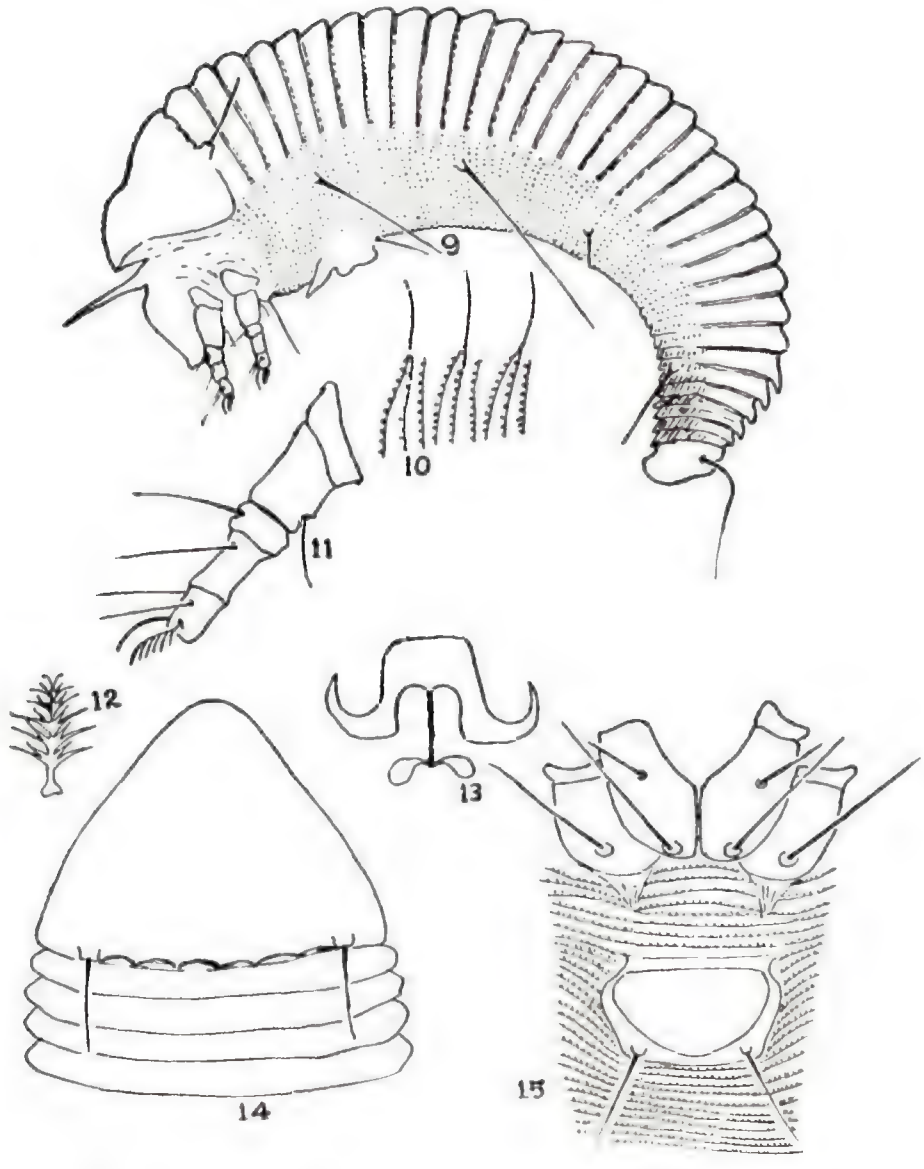


Figs : 1–8 : *Aculus ocimumae* sp. nov. 1. Side view of mite; 2. Fore-leg; 3. Side skin structure; 4. Side view of caudal end; 5. Feather claw; 6. Internal apodeme; 7. Dorsal view of anterior end. 8. Female genitalia and coxae from below.

Remarks: This species resembles *Aculus colei* Channabasavanna (1966) in its general appearance but could be differentiated from it by its 5 rayed feather claw, clear coxal areas; and the shield pattern.

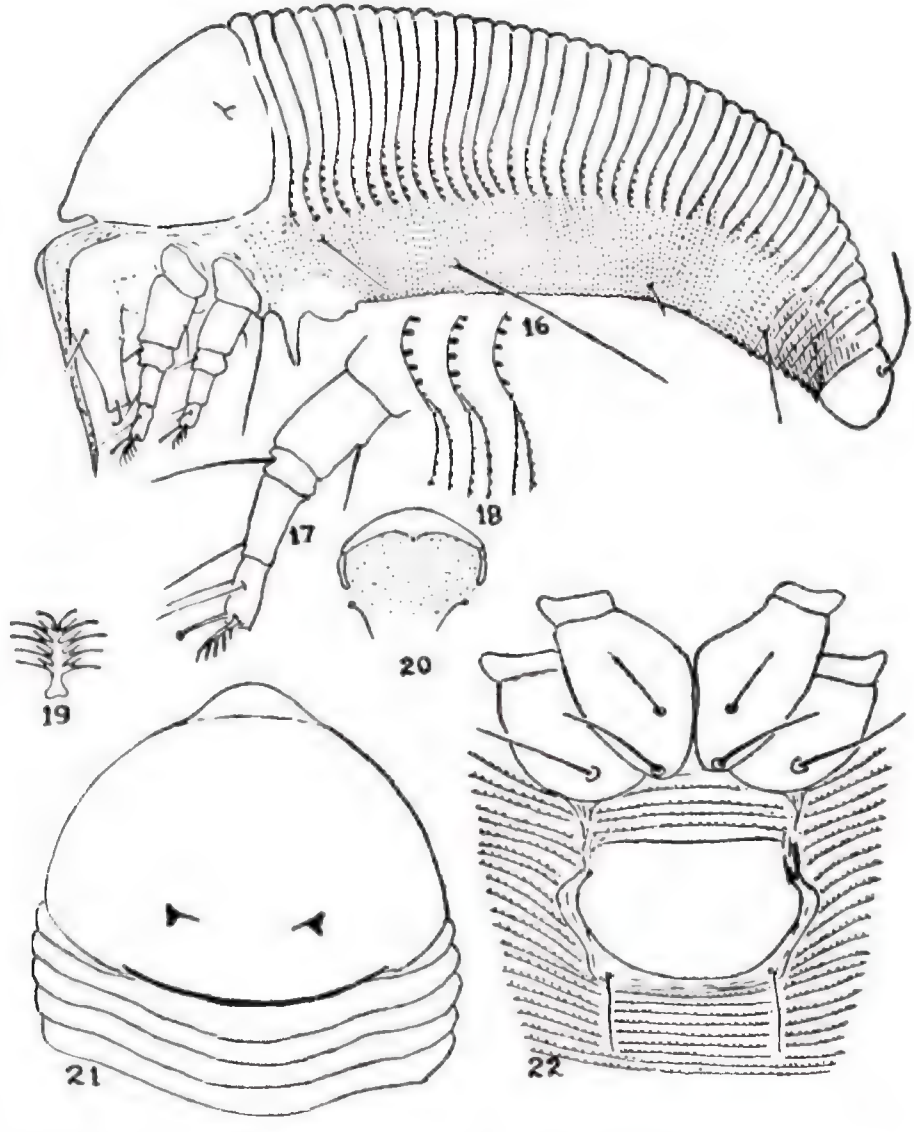
2. Anthocoptes bamboovagrans sp. nov. (Figs. 9–15)

Females: Worm like 230–250 long; 60–65 thick, rostrum 20–22 long down curved.



Figs. 9–15 : *Anthocoptes bamboovagrans* sp. nov. 9. Side view of mite; 10. Side skin structure, 11. Fore-leg; 12. Feather claw; 13. Internal apodeme; 14. Dorsal view of anterior end; 15. Female genitalia and coxae from below.

antapical seta not visible; shield 50 (48–52) wide, 30 (28–32) long; with no pattern of lines; sides of shield clear; dorsal tubercles at rear shield margin, 36 apart with a thick wavy line in between; dorsal setae 15 (14–16) long, pointing backwards. Fore-leg 30 long, tibia 6 long, tibial seta 10 long, thin at basal 1/3; tarsus 6 long; claw 7 long, curved and tapering; feather claw 6 rayed; hind-leg 28 long;



Figs. 16–22 : *Catarhinus munnarensis* sp. nov. 16. Side view of mite; 17. Fore-leg; 18. Side skin structure; 19. Feather claw; 20. Male genitalia; 21. Dorsal view of anterior end; 22. Female genitalia and coxae from below.

tibia 4 long; tarsus 6 long; claw 7 long, curved and tapering. Abdomen with about 35 (32–38) broad smooth tergites and 75 (70–80) finely micro-tuberculate sternites; lateral seta 38–40 long on ring 12; first ventral seta 68–70 long on about ring 30; second ventral seta 14 long on about ring 45; third ventral seta 12 long on ring 5 from behind; caudal seta 45 long, accessory seta absent. Female genitalia 22 wide, 14 long; coverflap smooth: genital seta 20 long.

Male: Not known

Types: A slide containing holotype (female) and three paratype slides with ♀♀, INDIA : Tamil Nadu : Coimbatore, 24. vii. 1989. ex. *Bambusa vulgaris* (Poaceae) : Coll. M. Mohanasundaram (No. 558, TNAU).

Remarks: The mites are under surface leaf vagrants, causing slight rusting symptoms. The present new species resembles *Anthocoptes ayyanari* Mohanasundaram (1981) in its clear coxal area, smooth genital coverflap and six rayed feather claw but could be differentiated from it by the clear smooth dorsal shield; position of the coxal tubercles II and III which are nearly in line; the shape of the internal apodeme; and the position and length of the fore-tibial setae. It also resembles *Anthocoptes walayarensis* Mohanasundaram (1981) in its smooth dorsal shield and coxal area, but differentiated from it by the smooth genital coverflap and six rayed feather claw.

3. Calacarus channabasavannae (Lukkundi, (1974)

Materials studied: INDIA: Tamil Nadu : Paramakudi, 21. xii. 1989 ex. *Emblica officinalis* (Euphorbiaceae) Coll. M. Mohanasundaram (No. 576, TNAU).

The pinkish mites are found in large numbers on the upper surface of the leaflets. When there is heavy population they also move to the lower surface of the leaflets as well. In older leaves, large number of white cast skins are seen due to the wax bearing lines on the mites. The affected leaves give a chlorotic appearance apart from the rusting symptoms caused due to their feeding. This mite has been earlier described from Karnataka on *Phyllanthus acidus*, on which they inhabit only the lower surface of the leaflets which are quite large. This is the first record of this mite on *Emblica officinalis*.

4. Calacarus jasmini Chakrabarti and Mondal (1978)

Materials studied: INDIA: Tamil Nadu: Paramakudi, 21. xii. 1989 ex *Jasminum sambac* Coll. M.Mohanasundaram(No. 577, TNAU).

The pinkish mites with five wax bearing lines found on the lower surface of the leaves, causing rusting symptoms. White cast skins of the mites seen on the lower surface of older leaves apart from the chlorotic condition of the older leaves. This species has earlier been described from West Bengal and is a new record for this region.

Catarhinus munnarensis sp. nov. (Figs. 16–22).

Female: 230–240 long, 90 wide; rostrum 25 long abruptly down curved, apical rostral seta 5 long, hooked at the tip, antapical rostral seta, thin 10 long; shield broadly triangular with a short, broad, blunt lobe over rostrum base; 90 wide, 56 long, shield area smooth; dorsal tubercles just away from rear shield margin, 20 apart; dorsal setae thin, 2 long, pointing inward. Fore-leg 40 long, tibia 10 long, tibial seta at the distal tip of the inner angle, 12 long; tarsus 8 long, claw 6 long, straight with a knobbed tip, feather claw simple, 5 rayed, broad, appearing as divided in ventral view; hind-leg 36 long, tibia 7 long; tarsus 7 long; claw 6 long, straight and knobbed at tip. All usual leg setation present on both legs. Coxae broadly joined with a clear sternal line, all three setiferous tubercles present; coxal tubercles I in the middle fore-coxae; coxal tubercles II at base of fore-coxae, nearly in line with tubercles III of hind-coxae; coxal area smooth without any markings.

Abdomen with a slight subdorsal furrow on either side; about 40 tergites and about 80 finely microtuberculate sternites; lateral seta 12 long on ring 12; first ventral seta

45 long on about ring 26; second ventral seta 4 long on about ring 48; third ventral-seta 16 long on ring 6 from behind; caudal seta 20 long; accessory seta absent; female genitalia 30 wide, 18 long, near the coxal base; coverflap smooth; genital seta 10 long.

Male: 200 long, 70 wide; genitalia 18 wide, genital seta 7 long.

Types: A slide containing holotype (Female) with several ♀♀ and 4 paratype slides with ♀♀ and ♂♂; INDIA: Kerala: Munnar above 3000 feet MSL; 20. ix. 1989. ex. *Bambusa* sp. (Poaceae), Coll : M. Mohanasundaram (No. 580, TNAU).

6. **Rhombacus morrisi** Keifer (1965)

Materials studied: India: Tamil Nadu: Coimbatore, Coll: M. Mohanasundaram (No. 570, TNAU).

This mite has earlier been described and recorded only from Australia on *Eucalyptus viminalis* Labill causing witche's broom of the shoot (Keifer, 1965 and Jeppson *et al.*, 1975). This is the first record of this mite from the Indian region and the host also is a new record. On *Eucalyptus teraticornis* this broadly wedge shaped, dorsoventrally flattened yellowish mites, cause severe rusting and chlorosis of the leaves and are found on both surfaces of the leaves. No witche's broom effect was noticed on this host.

7. **Tegonotus convolvuli** Channabasavanna (1966)

Materials studied: INDIA: Tamil Nadu : Paramakudi 21. xii. 1989. ex *Ipomoea carnae* (Convolvulaceae) Coll : M. Mohanasundaram (No. 578, TNAU).

This broad, wedge shaped, yellowish brown mite has been recorded as a pest of sweet potato *Ipomoea batatas* (Channabasavanna, 1966; Jeppson *et al.*, 1975) where it causes severe rusting symptoms. This mite has been collected from *Ipomoea carnea* which is a hedge plant and also grows in marshy areas. On this host, the mites were found as under surface leaf vagrants without causing any rusting symptoms and is a new host record.

8. **Tegonotus mangiferae** (Keifer, 1946)

(= *Oxypleurites mangiferae* Keifer)

Materials studied: INDIA: Tamil Nadu: Coimbatore, i. ix. 1989, ex *Mangifera indica* Linn. (Anacardiaceae), Coll M. Mohanasundaram (No. 572, TNAU).

This mite has white wax filaments on the body and found on the lower surface of the leaves causing slight rusting symptoms. This is the first record of this mite in India. Earlier it has been recorded only from Hawaii (Garrett and Haramoto, 1967; Jeppson *et al.*, 1975).

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Entomon 1991 Vol. 16 No. 3 pp. 193 to 201

AN ENERGY BUDGET OF LARVAL STAGES OF *DICRANOGNATHUS NEBULOSUS* REDT. (COLEOPTERA : ATTELABIDAE)

B. R. KAUSHAL & SHAMILA KALIA
Department of Zoology, Kumaun University, Nainital, India 263002

(*Received* 23 *March* 1990)

An energy budget of larval stages of *Dicranognathus nebulosus* Redt. reared on kernels of oak, *Quercus leucotrichophora* A. Camus was constructed. Maximum consumption, faeces and conversion were recorded in the third instar larva. Larvae ingested a total of 3887.37 cal insect^{-1} of kernels and egested 1536.57 cal insect^{-1} (39.6%) during their developmental period. Larval stages assimilated between 59 to 73% of the food consumed and the proportion of assimilated energy converted into tissue growth increased from 7.7 to 27.6% during development.

(*Key words:* energy budget, *Dicranognathus nebulosus*, Coleoptera)

INTRODUCTION

The oak forests in the Himalayas are of paramount importance in being used as firewood and checking soil erosion. One of the principal causes of their poor regeneration are infestations by acorn weevil, *Dicranognathus nebulosus* Redt. (Coleoptera: Attelabidae). KAUSHAL & KALIA (in press) have reported the extent of damage and control measures for this insect in the oak forests of Nainital and environs. No information is available on the energy budget of larval stages of this insect.

The present investigation deals with the energetics of larval stages of *D. nebulosus*.

MATERIALS AND METHODS

Acorns of *Quercus leucotrichophora* A. Camus dropped on the ground in the oak forests (altitude 1700–2200 m) of Nainital and environs (29°23'N lat. and 79°77'E long.) were collected by hand picking during 1984–1987. These were then brought in the laboratory and separated into infested and uninfested acorns. The infested acorns are characterised by the presence of a black secretion near the site of oviposition and indicating the presence of eggs of *D. nebulosus* inside. This was further confirmed by tearing the acorn. Newly hatched, first instar larvae (n = 150) were reared to maintain a stock culture in petri-dishes of 15 cm diameter with a gauze top. The larvae were held at room temperature (20 to 25°C) and a relative humidity (60 to 65%). Upon hatching, the larvae were provided with fresh food (kernels of acorns) *ad libitum*. Blotting paper was placed at the bottom of each petri-dish and kept moist to prevent drying of food (RH 60 to 80%). Care was taken that food always remained in excess.

The actively feeding larvae, were deprived of food for about 30 minutes before and after the feeding to prevent the carry over faecal matter from the gut. Preparatory experiments of VATS *et al.* (1977) had shown that active egestion in larvae selected for feeding experiments almost ceases within 30 minutes of the withdrawal of food.

Before the start of experiment, larvae (n = 15) of known initial live weight were

held singly in a separate petri-dish, with an excess of preweighed food. The first instar larvae, being small, were kept in a group of ten and an average value for each replicate was calculated. The larvae which died during the course of experiment were replaced by larvae of approximately the same age from the stock culture. After 24 h of feeding, the larvae were reweighed. Similarly, uneaten food and faeces were collected, oven dried at 80°C for 48 h and weighed to a constant weight.

Food consumption was calculated as the difference between the initial weight of the food provided and the uneaten food after 24 h of feeding. Dry weight to live weight ratio of the food consumed were obtained by the percentage of dry matter in the cotyledons of acrons (WALDBAUER, 1968). The percentage dry matter was obtained by drying cotyledons of acorns (n = 25) at 80°C for 48 h. The dry weight was expressed as percentage of fresh weight of the kernels. Similarly, dry weight equivalents of larvae were obtained by oven drying of 34 individuals of each stage. Assimilation was calculated by subrtracting the weight of egesta from the weight of food consumed, while increase in body weight was taken as a measure of tissue growth (DELVI & PANDIAN, 1972.

Ecological efficiencies were calculated as described by WALDBAUER (1968).

The energy values of kernels, larval instars and egesta were determined by adiabatic bomb calorimetery. The caloric value of each instar could not be determined separately because of small quantity of material and thus caloric value of larval instars was calculated collectively. The dry weights of energy budget parameters were multiplied by their appropriate equivalents to give their mean energy content in calories. Energy budget of adult *D. nebulosus* has not been constructed because they do not feed on acorns as adults.

OBSERVATIONS AND DISCUSSION

Caloric value:

The caloric values per mg dry weight of different biological materials are presented in Table 1. The average caloric value of the larval instars was recorded as 5.477 ± 0.66 cal mg^{-1}. The highest caloric value was observed (6.069 cal mg^{-1}) in the prepupa, indicating a build up of energy reserves such as lipids for use in non-feeding pupal stage (PRUS, 1970; CAMPBELL *et al.*, 1976; SINGH & SINHA, 1977; DUTCHER, 1982). KLEKOWSKI *et al.* (1967) reported highest value in the prepupae of *Tribolium castaneum* (Herbst). The ash free caloric value for the 4th instar of *Tenebrio molitor* L was 6.314 cal mg^{-1} (SLOBODKIN & RICHMAN, 1961). CAMPBELL & SINHA (1974) reported highest value (6.54 cal mg^{-1}) in the 4th instar and prepupa of *Sitophilus granarius* (L.). Energy values ranged from 5.570 to 6.445 cal mg^{-1} in *Cryptolestes ferrugineus* (Stephens) and *Rhizopertha dominica* (F.) feeding on wheat kernels. The caloric content of the 4th instar larvae of pecan weevil, *Curculio caryae* Horn was much higher (8.0 cal mg^{-1} ash free dry wt.; DUTCHER, 1982). However, the energy content of animal populations, in general, is within the range of 5.4 to 6.4 cal mg^{-1} ash free dry weight except during periods of specific demands (SLOBODKIN, 1961). WALDBAUER (1968), AXELLSON *et al.* (1974), VATS & KAUSHAL (1980) have also reported higher caloric value for food than egesta as has been recorded in the present study.

TABLE 1. Calorific content (cal. mg^{-1} dry wt.) of different biological materials (mean ± S D) (all values based on ash free dry weight).

Biological materials	Caloric value (Cal. mg^{-1} dry wt.)
Larvae (all instar)	5.477 ± 0.66
Faeces (all instars)	4.639 ± 0.33
Food plant (kernels of acorn)	5.824 ± 0.13
Prepupae	6.069 ± 0.04
Pupa	6.03 ± 0.15

TABLE 2. Initial body weight, consumption, faeces, assimilation and conversion in *D. nebulosus* fed on acorns of *O. leucotrichophora*.

Stages	Duration (days)	Initial body weight (cal. $insect^{-1}$)	Consumption (Cal. $insect^{-1}$ day^{-1})	Faeces (Cal. $insect^{-1}$ day^{-1})	Assimilation (cal. $insect^{-1}$ day^{-1})	Conversion (cal. $insect^{-1}$ day^{-1})
First instar	26.2 ± 0.55	0.45 ± 0.09	5.7 ± 0.26	1.55 ± 0.08	4.16 ± 0.21	0.317 ± 0.08
Second instar	53.9 ± 1.27	2.08 ± 0.28	9.8 ± 0.32	3.09 ± 0.10	6.17 ± 0.22	0.843 ± 0.15
Third instar	230.8 ± 2.15	8.95 ± 1.04	13.89 ± 0.36	5.76 ± 0.15	8.14 ± 0.22	2.247 ± 0.23

TABLE 3. Feeding rate parameters for consumption, assimilation and conversion (cal. cal^{-1} day^{-1}) in *D. nebulosus* larvae fed on acrons of *Q. leucotrichophora* (mean ± 1 SD).

Stages	Consumption (Cal. $cal^{-1}day^{-1}$)	Faeces (Cal. cal^{-1} day^{-1})	Assimilation (Cal. cal^{-1} day^{-1})	Conversion (Cal. $cal^{-1}day^{-1}$)
First instar	12.67 ± 4.13	3.44 ± 1.03	9.23 ± 0.62	0.704 ± 0.055
Second instar	4.71 ± 0.92	1.48 ± 0.29	3.23 ± 0.13	0.405 ± 0.035
Third instar	1.55 ± 0.17	0.64 ± 0.07	0.91 ± 0.02	2.25 ± 0.08

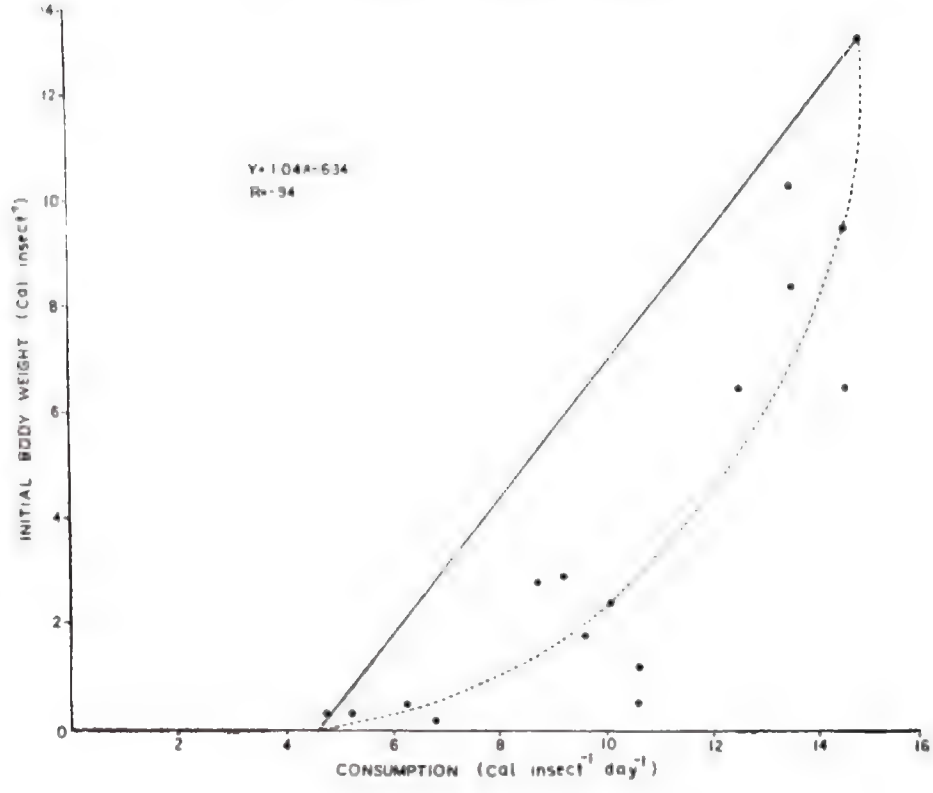

Figure 1. Relationship between food consumed and initial body weight in different larval instars. $Y = 1.04 x - 6.34$ ($r = -0.94$, $p > 0.01$) The regression line is shown by a solid line while the broken line represents a non-linear curve fitted by eye.

Food consumption, Assimilation and Tissue growth conversion:

The data on initial body-weight, cosumption, faeces, assimilation and conversion in different larval instars of *D. nebulosus* are presented in Table 2.

Initial biomass;

The initial body-weight of the larva increased from 0.45 cal insect^{-1} at hatching in the first instar to 8.95 cal insect^{-1} in the third instar. Second and third instars comprised more than 96% of the total initial body weight. The last two instars of insects contributed more than 95% of the total initial body weight (AXELLSON *et al.*, 1974; SINGH *et al.*, 1976; CAMPBELL & SINHA, 1978).

Consumption:

The consumption increased with the increase of body weight. The larvae consumed 5.7 (19.39%), 9.8 (33.35%) and 13.86 cal insect^{-1} day^{-1} (47.26%) in the first, second and third instar, respectively. A significant relationship was observed when initial body weight was plotted against consumption (Fig. 1). The last two instars showed a rapid increase in food consumed (AXELLSON *et al.*, 1974; SINGH *et al.*, 1976; CAMPBELL & SINHA, 1978).

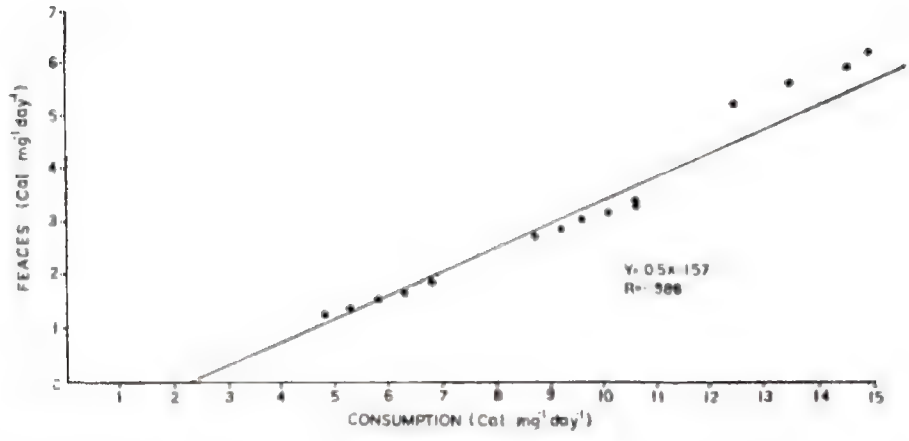

Figure 2. Relationship between consumption and faeces. $Y = 0.5\,x - 1.57$ ($r = -0.988$, $p > 0.01$)

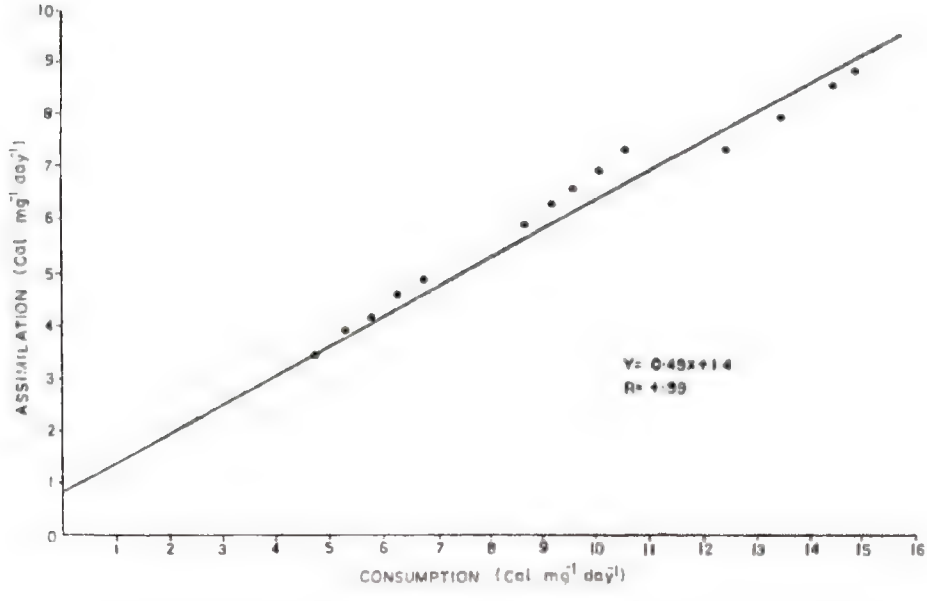

Figure 3. Relationship between assimilation and consumption. $Y = 0.49\,x + 1.4$ ($r = 0.99$, $p > 0.001$)

However, when feeding rate (calories of food per calorie of insect per day) was considered, values decreased from first to third instar (Table 3). Maximum feeding rate was obtained in the first instar and minimum in the third instar. CAIRNS (1982) also reported that feeding rate declined from first to third instar larva of *Rhopacea verreauxi* Blanch.

Feaces:

Higher consumption in the second and third instar larvae resulted in 29.71% and 55.38% of the total egesta, respectively. The larvae had lost 39.6% of the consumed energy as faeces and excretory products on reaching prepupal stage. Weight-

specific egestion also decreased from first to third instar larvae. A linear relationship was obtained when feaces was plotted against consumption (Fig. 2).

Sitophilus oryzae (L.) lost 18.36% as egesta of the consumed energy (SINGH *et al.*, 1976) while *C. ferrugineatus* and *R. dominica* lost 30.0% and 73.2% of the consumed energy (CAMPBELL & SINHA, 1978), respectively. Pecan weevil 4th instar larvae egested 11.09% of the consumed energy (DUTCHER, 1982).

Assimilation :

A total of 19.01 cal insect^{-1} day^{-1} was assimilated by the three larval instars; the last two assimilating more than 85%. Assimilation increased from 4.16 $\pm$ 0.21 in the first instar to 8.14 $\pm$ 0.22 cal insect^{-1} day^{-1} in the third instar. However, assimilation rate declined from first instar to the third instar (Table 3).

A positive linear relationship was obtained when assimilation was plotted against consumption (Fig. 3).

Conversion :

Increase in body wieght has been considered as tissue growth. The distribution of conversion in the first, second and third instars is : 9.36, 24.73 and 65.01% of the total conversion, respectively. Total conversion was 3.409 cal insect^{-1} day^{-1} in the three larval stages indicating that larvae utilized only 11.6% of the consumed energy.

Larvae of *S. oryzae* utilized 20.05% of the total consumed energy towards production (SINGH *et al.*, 1976). Fourth instar larvae of pecan weevil utilized only 5.38% of consumed energy in production (DUTCHER, 1982).

Conversion rate declined from first instar to the third instar larvae (Table 3). CAIRNS (1982) also reported that conversion rate declined in *R. verreauxi* larvae.

Conversion values in the present study are under-estimated as exuvial production has not been considered. KLEKOWSKI *et al.* (1967) have, however, reported that larval exuviae represent 8.3% of the net larval production before pupation.

Fig. 4 represents the relationship between tissue growth and consumption. The re-

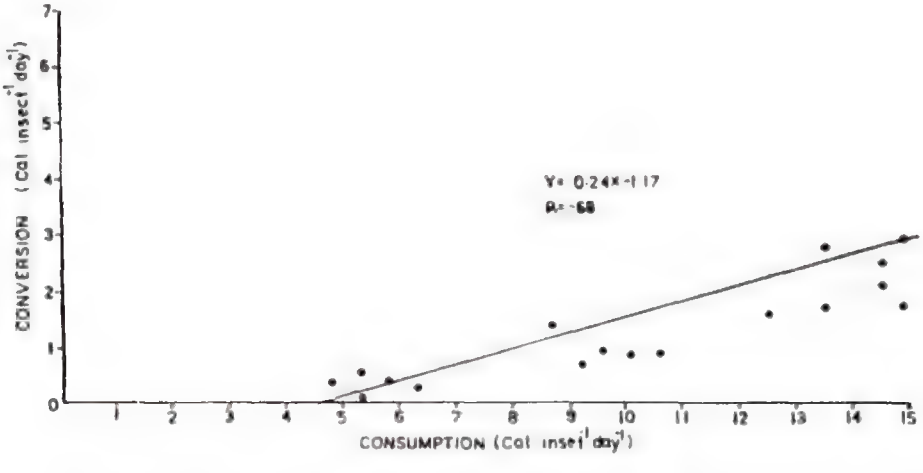

Figure 4. Relationship between conversion and consumption. Y = 0.24 x –0.117 (r = –0.68, $p > 0.01$)

gression line intersects the ordinate at a point below zero, showing that tissue growth occurred only on taking food.

Efficiencies of food Utilization :

Ecological efficiency ratios are useful in comparing different animal populations in terms of their apportionment of energy resources (REICHLE, 1971).

Data on per cent values of assimilation efficiency (AD), tissue growth efficiency (ECD) and ecological growth efficiency (ECI) into body tissue are given in Table 4.

The assimilation efficiency of *D. nebulosus* decreased from a mean maximum of 72.89% (range 72.44 to 73.32%) in the first instar larva to a mean minimum of 58.59% (range 58.41 to 58.71%) in the third instar larva, indicating that assimilation efficiency decreased with increasing age.

Such a response is not uncommon. Assimilation efficiency decreased with increasing age in insects from different trophic levels (LAWTON, 1970; MUKERJI & GUPPY, 1970; OTTO, 1974; HAGVAR, 1975; VATS *et al.*, 1977; KAUSHAL & VATS, 1984 a). It has been reported that this is the norm for insects, both herbivores (WALDBAUER, 1968) and carnivores (LAWTON, 1970). However, WOODLAND *et al.* (1968), HOLTER (1974), RANDOLPH *et al.* (1975), GRAFIUS & ANDERSON (1979) have reported that assimilation efficiency is not related to either age or size.

Assimilation efficiencies of insects feeding on grains and seeds vary from 60–95% during development (KLEKOWSKI *et al.*, 1967; GRIMM, 1973; CAMPBELL *et al.*, 1976; SINGH *et al.*, 1976; CAMPBELL & SINHA, 1978; SLANSKY & SCRIBER, 1982).

Assimilation efficiency largely depends upon the type of food, the insects eat (WOODLAND *et al.*, 1968) assuming they are reared under favourable temperatures and relative humidities. *Tenebrio molitor* L. reared on the fibrous medium of wheat bran had an assimilation efficiency of only 46% (EVANS & GOODLIFFE, 1939). *S. oryzae* and *S. granarius* fed on meridic diet had higher assimilation efficiencies (95 and 88%, respectively; BAKER, 1974) than those reared on whole wheat kernels (79 and 76%, respectively; CAMPBELL *et al.*, 1976; SINGH *et al.*, 1976).

The larvae in the present study were fed on what could be termed their natural diet of cotyledons of acorns. Variation in assimilation efficiency as a result of variations in quality of food available were not anticipated.

TABLE 4. Efficiencies of food utilisation in the larva of *D. nebulosus* fed on the acorns of *Q. leucotrichophlra* (mean ± 1 SD)

Stages	Assimilation efficiency (AD) (%)	Tissue growth efficiency (ECD) (%)	Ecological growth efficiency (ECI) (%)
First instar	72.89 ± 0.14	7.67 ± 2.08	5.6 ± 1.51
Second instar	68.44 ± 0.04	13.66 ± 2.59	8.6 ± 1.77
Third instar	58.59 ± 0.04	27.6 ± 2.42	16.18 ± 1.42
Mean	66.64	16.31	10.13

The tissue growth efficiency (ECD) also showed an increase from 7.67% (mean) in the first instar larvae to 27.6% (mean) in the third instar larvae (Table 4), suggesting that latter were more efficient in transforming assimilated energy into body tissue.

KLEKOWSKI *et al.* (1967), SINGH *et al.* (1976), CAMPBELL & SINHA (1978) have also reported an increase in ECD with increase in body weight. ECD ranged from 3.8 to 20.4% in the fourth instar pecan weevil larva (DUTCHER, 1982). The ranges of ECD for nine species of grain and seed feeding immature chewing insects varied from 2–59% (SLANSKY & SCRIBER, 1982).

Thus, ECD values in the present study fall in the range of reported values.

The ecological growth efficiency or efficiency of conversion of ingested food into body tissue (ECI) showed a gradual increase from 5.6% (mean) in the first instar to 16.18% (mean) in the third instar larvae.

The ECI values obtained in the present study are similar to that (20%) of *T. castaneum* (KLEKOWSKI *et al.*, 1967); 15.6 to 19.7% of *Leptoterna dolobrata* (MCNEIL, 1971); 10 to 20% (CAMPBELL & SINHA, 1978); 3.3 to 17.9% in pecan weevil larvae (DUTCHER, 1982); and 2.4 to 40.7% in *R. verreauxi* larvae (CAIRNS, 1982).

Total consumption by Larval instars :

Larvae ingested a total of 149.34, 528.22 and 3205.81 cal insect^{-1} in the first, second and third instars, respectively during their entire developmental period. Larvae thus consumed 20.87% of 81.04 $\pm$ 0.19 K cal acorn kernel per infested acorn.

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Entomon 1991 Vol. 16 No. 3 pp. 203 to 207

GROWTH, FECUNDITY AND HATCHABILITY OF EGGS OF *BOMBYX MORI* L. IN RELATION TO REARING SPACE

N. ROYCHOUDHURY, D. C. PAUL & G. SUBBA RAO
Central Sericultural Research and Training Institute, Berhampore,
West Bengal, India 742 101

(*Received* 23 *May* 1990)

An experiment was carried out under the climatic condition in the plains of West Bengal following Japanese, Indian and Chinese spacing schedules for bivoltine silkworm, *Bombyx mori* L., to find out the growth of different developmental stages, number of eggs laid and hatching performance of bivoltine hybrid 'NB_{18}' × 'P_5'. Results revealed that among the spacing schedules, wider spacing as per Chinese recommendation played a significant ($P<0.05$) and positive role for improvement of larval, pupal and imaginal weight, fecundity and hatching performance of eggs, whereas crowded condition was found to be detrimental reflected by Japanese spacing schedule. Indian spacing schedule exhibited the performance in between Japanese and Chinese except for the hatching potentiality.

(*Key words:* larva, pupa, adult, fecundity, hatching, spacing, silkworm, *Bombyx mori*)

INTRODUCTION

Insect growth and development proceed optimally under certain population densities, but caterpillars are adjusted to a wide range of population densities (SEHNAL, 1985). Density of larval population has a great impact on biology, morphology and physiology of insects (PETERS & BARBOSA, 1977). Larval crowding due to inadequate rearing seat space has been found to increase the duration of larval life and mortality, reduce the larval, pupal and imaginal weights and affect morphology, longevity, fecundity and fertility of the resulting adults in several representatives of the order Lepidoptera (IWAO, 1968 ; MANSOUR & DIMETRY, 1972 ; HINTON, 1981 ; FESCEMYER & HAMMOND, 1988). Information is lacking on the effectivity of rearing space on larval, pupal and imaginal weight, number of eggs laid and hatchability of silkworm eggs. The present study is therefore, planned to fill these lacunae following spacing schedules for bivoltine silkworm (*Bombyx mori* L.) as recommended by Japanese, Indian and Chinese, under the climatic condition in the plains of West Bengal, using bivoltine hybrid 'NB_{18}' × 'P_5' as an experimental insect.

MATERIALS AND METHODS

Larvae of 'NB_{18}' × 'P_5' were reared on mulberry leaves *Morus alba* L. (variety 'S_1') in an uncontrolled condition inside a rearing room and the experiment was conducted in the month of January-February 1989, when the temperature and relative humidity were 20 - 28°C and 46 - 81% respectively. Spacing schedules (Table 1) for bivoltine silkworm larvae as recommended by Japanese (T_1), Indian (T_2) and Chinese (T_3) were considered (IYENGAR *et al.*, 1988). The experiment was started with one replication for each schedule separately containing 1000 worms upto third instar (called chawki rearing: KRISHNASWAMI, 1988) while fourth instar onwards till spinning each schedule consisted of five replications with 200 worms in each. Similarly, one control was maintained with identical con-

TABLE 1. Recommended spacing schedule (m^2) for 20, 000 larvae of bivoltine silkworm*.

Instar	Japanese	Indian	Chinese
I	0.11 — 0.82	0.20 — 0.81	0.84 — 1.17
II	0.82 — 1.64	0.81 — 2.44	2.51 — 2.84
III	1.64 — 3.28	2.44 — 5.57	5.84 — 6.60
IV	3.30 — 7.30	5.57 — 11.15	11.67 — 14.00
V	7.30 — 18.90	11.15 — 22.30	23.34 — 27.84

* IYENGAR *et al.* (1988).

ditions for replacement of unequal and dead larvae. Area (spacing) for larvae of different instars and days were maintained very strictly limiting the boundary with a wooden frame. Before attaining the adult stage, larvae passed through pre-spinning phase (called as mature larvae: (RANGASWAMI *et al.*, 1976) and then pupal stage. Sufficient number (n = 10) of such developmental stages, in the same age groups (0-6 h), were collected and weighed randomly from all the replications of three spacing schedules separately. The weighed moths were allowed to lay eggs replicationwise after mating of 3 h (recommended coupling duration: RANGASWAMI *et al.*, 1976) and the number of eggs laid and number of eggs hatched were counted separately for each replication of spacing schedule. The nature of significance in the differences of mean values of the weight of different developmental stages, fecundity and hatching percentage in three spacing schedules were tested by analysis of variance.

RESULTS

The duration of larval life, among the three spacing schedules, was found to be reduced in T_2 and T_3 (30 days) by 12 h from T_1 (30.5 days), but there was no difference between T_2 and T_3. However, T_3 exhibited the best performance and highest gain in all the characters that were examined (Tables 2 and 3).

Under the three spacing schedules, the maximum weight of mature larvae (pre-spinning larvae) was attained in T_3 which differed significantly ($P<0.05$) from the other two (Table 2) and gain over T_1 and T_2 were 17.51 and 10.55% respectively (Table 3). Again, T_2 showed significantly ($P < 0.05$) higher than T_1 (Table 2).

Pupae developed after larval rearing under three spacing schedules showed highest weight in T_3, both in male and female and both differed significantly ($P<0.05$) from T_2 and T_1 (Table 2). The percentage gain of T_3 over T_1 and T_2 in regard to male pupae were 15.57 and 6.56% respectively and female pupae were 13.84 and 8.81% respectively (Table 3). Further, difference between T_1 and T_2 was found significant ($P<0.05$) and showed more in T_2 followed by T_1, both for male and female pupae (Table 2).

The adults developed after larval rearing under three spacing schedules exhibited highest wieght in case of T_3 both for male and female, and were significantly ($P<0.05$) different from T_1 and T_2 (Table 2). The percentage gain of T_3 over T_1 and T_2 in respect to male and female adults were

TABLE 2. Data (mean±SE) on weight of different developmental stages, egg laying and hatching percentage obtained after rearing of bivoltine hydrid 'NB_{18}' × 'P_5' under three spacing schedules.

Spacing & indices		Weight of mature larva* (g)	Weight of pupa		Weight of adult		Number of eggs laid/ Female	Hatching %
			Male (g)	Female (g)	Male (g)	Female (g)		
Japanese	T_1	4.38	1.03	1.37	0.38	0.79	505.20	93.04
		±0.05	±0.01	±0.01	±0.01	±0.01	±1.74	±0.79
Indian	T_2	4.75	1.14	1.45	0.48	0.88	526.20	92.90
		±0.09	±0.04	±0.03	±0.02	±0.01	±9.19	±0.79
Chinese	T_3	5.31	1.22	1.59	0.56	0.96	563.60	95.52
		±0.03	±0.02	±0.03	±0.02	±0.01	±6.35	±0.26
C D at 5%		0.21	0.07	0.05	0.04	0.05	20.23	2.04

*Pre-spinning larva, C D = Critical difference.

TABLE 3. Percentage gain on weight of different developmental stages, egg laying and hatching percentage of bivoltine hybrid 'NB_{18}' × 'P_5' under Chinese spacing over Japanese and Indian.

Characters	Over Japanese	Over Indian
Larval weight	17.51	10.55
Pupal weight		
Male	15.57	6.56
Female	13.84	8.81
Imaginal weight		
Male	32.14	14.29
Female	17.71	8.33
Number of eggs laid/female	10.36	6.64
Hatching %	2.60	2.74

32.14, 14.29% and 17.71, 8.33% respectively (Table 3). Again, between T_1 and T_2, significant ($P<0.05$) difference existed both for male and female adults, and found to be more in T_2 than T_1 (Table 2).

The emerged moths of three spacing schedules showed a significant ($P<0.05$) difference in the number of eggs laid/ female and highest number was recorded in T_3 (Table 2). The percentage gain of T_3 over T_1 and T_2 were 10.36 and 6.64% respectively (Table 3). Further, T_1 and T_2 differed significantly ($P<0.05$) and T_2 showed more number than T_1 (Table 2).

The hatching percentage was also found to be maximum in T_3 which differed significantly ($P<0.05$) from T_1 and T_2 (Table 2) and gain of T_3 over T_1 and T_2 were 2.60 and 2.74% respectively (Table 3). Further, the difference between T_1 and T_2 was not significant ($P>0.05$) (Table 2).

DISCUSSION

The present findings demonstrate that the growth of *B. mori* is related with larval rearing space which again related with the reproductive potentiality of both male and female moths. This is very much reasonable because, in silkworm, provision of adequate rearing seat space is of vital importance, at every stage of rearing for vigorous growth and robust health, and the density of population in the rearing bed should be maintained in such a way that the

ideal microclimatic conditions of bed is ensured (RANGASWAMY *et al.*, 1976 ; JOLLY, 1987; KRISHNASWAMY, 1988).

The shortening of the larval period as recorded in Chinese and Indian spacing compared to Japanese is surely an unique result of the present experiment. This observation indicates that population density has a role in physiological programming of larvae in relation to spacing and are in agreement, in a general way, with the findings recorded on many other lepidopteran insects (MANSOUR & DIMETRY, 1972; CHAPMAN, 1973; FESCEMYER & HAMMOND, 1988).

Since in the present investigation, among the three spacing schedules, wider spacing as per Chinese recommendation has significantly ($P < 0.05$) improved the larval, pupal and imaginal growth considered by weight. This finding may corroborate the observation of SENGUPTA & YUSUF (1974) who noted that in multivoltine breeds of silkworm, larger spacing help to improve the growth. This is possible because the normal behaviours such as free feeding and movement of a particular species is of prime importance amongst those factors involved in the response of insect to the population density (IWAO, 1968). This result has got parallelism with earlier workers (reviewed by HINTON, 1981).

According to HINTON (1981) there exists a relation between larval density and fecundity because differences in the size of the larvae or later stages are directly related to fecundity, which agree with the present findings and is, in complete agreement with the results of RAPUSAS & GABRIEL (1976) in *B. mori*. Further, weight of the female is directly related to its weight as a pupa and as a larva, and there is therefore usually a close relation between the fecundity of the adult and the weight of its pupa and larva, as noted by many workers (HINTON, 1981), and have come to conclusion hat heavier or larger adults tend to lay more eggs than smaller ones. The present results also support the same view.

The present finding may not be a contradiction to this as there exhibits a highest percentage of hatching by highest weight of male moths, because, in silkworm, it has been recorded that optimum weight of male moth is required to get the maximum fertilized eggs which differs with voltinism (GUPTA *et al.*, 1986).

All these results definitely point out to the positive influence of wider spacing as per Chinese schedule under the plains of West Bengal for the successful rearing of bivoltine silkworm and thereby to improve the larval growth, fecundity and hatchability, and also economic characters of cocoons (unpublished observations of the present author).

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Entomon 1991 Vol. 16 No. 3 pp. 209 to 212

INFLUENCE OF ABIOTIC FACTORS ON LARVAL DURATION AND COCOON YIELD OF SILKWORM, *BOMBYX MORI* L.: A SEARCH FOR SUITABLE REARING HOUSE

SANTOSH K. GANGWAR & P. SOMASUNDARAM
Regional Sericultural Research Station, Allikuttai P. O., Gandhinagar, Salem, Tamil Nadu, India 636 003

(*Received* 12 *August* 1990)

Three years' survey data on rearing of silkworm cross breed ('PM' × 'NB_4D_2') in different types of rearing houses of sericulturists in Tamil Nadu revealed that thatched roof mud house with cooler climatic conditions than tiled house and RCC building enchanced the larval duration and cocoon yield. Months with cooler atmospheric temperature also showed similar results when compared to hot months. Average values of maximum temperature of the months had a strong negative correlation with the larval duration and cocoon yield. Relative humidity reflected its influence on the larval duration only. The role of abiotic factors in modulating the larval duration and cocoon crop is discussed.

(*Key words:* silkworm, rearing houses, abiotic factors, larval duration, cocoon yield)

INTRODUCTION

Silkworm, being poikilotherm, changes its body temperature according to the environmental temperature influencing its physiology. Though optimum temperature of 23-28°C and relative humidity of 70–90% have been reported for silkworm rearing (KRISHNASWAMI *et al.*, 1973), these conditions seldom exist in the rearing houses of sericulturists who use various types of buildings viz., mud wall thatched roof house, tiled house and RCC building depending upon their socioeconomic status. Sericultural scientists recommend well defined model rearing house with appropriate ventilation and encircling verandah to keep it hygienic and protected against natural enemies like uzifly by providing spring doors and wire mesh on doors and windows. Pucca rearing houses of sericulturists do not fulfil these conditions owing to limited resources. A case study was made to evaluate the suitability of three types of rearing houses viz., mud wall thatched roof house, tiled house and RCC building under sericulturists' practices in Tamil Nadu taking abiotic factors of the rearing houses like temperature and relative humidity into consideration.

MATERIALS AND METHODS

Three types of rearing houses viz., mud wall thatched roof house, tiled house and RCC building were selected in five villages around Salem (11°5 'N Lat., 78°4'E Long.). Cross breed silkworm ('PM' × 'NB_4D_2') was used throughout the experiment. Disease free layings were reared up to 2nd moult at chawki rearing centres of Central Silk Board during each month and then distributed amongst different types of houses mentioned earlier. The number of DFLs in different houses varied depending upon the availability of mulberry leaf with the farmers. As one sericulturist could take only six crops in a year, another set

Present address (also for correspondence): Regional Sericultural Research Station, Peepe Compound, Main Road, Ranchi 834 001, Bihar.

of sericulturists of respective types of rearing houses was selected to cover remaining six months. Silkworm crops were timely supervised for proper feeding and maintaining hygienic conditions. Larval duration and cocoon yield were recorded at the end of each rearing. After three years, the data were compiled and compared for suitability of rearing houses under the sericulturists' practices in Tamil Nadu.

Macroclimatic factors like maximum temperature, minimum temperature and relative humidity of each type of rearing house were collected from the records of Regional Sericultural Research Station, Salem. Monthly mean values were worked out and correlation analysis of macroclimatic factors, larval duration and cocoon yield was made to find out their relations.

RESULTS AND DISCUSSION

The larval duration was maximum in mud wall thatched roof house (26.8 days) followed by tiled house (26.1 days) and RCC building (25.3 days) (Table 1). The mud wall thatched roof house showed maximum cocoon yield (40.7 kg/100 DFLs) followed by tiled house (36.2kg/100 DFLs) and RCC building (31.08 kg/100 DFLs). Monthly mean values in three types of rearing houses showed that larval duration was more during cool atmospheric conditions prevailing in the months of Jan, Feb, Nov, and Dec as compared to hot climatic conditions of Mar - May and Aug - Oct months. The temperature data plotted in Table 1 confirmed the cooler and hotter months. It also showed that in RCC building during summer the temperature was much higher than that in tiled house and thatched mud house. It is known that higher temperature enhances metabolism in insects (MUTHUKRISHNAN, 1980) thereby hastening the life cycle duly reducing the larval duration in silkworm. Similar rsults were found presently. Regarding reduced cocoon yield in RCC building, it may be recalled that metabolic rate and insect growth are reverse phenomena (CALOW, 1977; MUTHUKRISHNAN, 1980). Further, the larvae maintained at higher temperature might utilise most of the stored lipid for general maintenance (catabolic activities) and thereby the energy allocated for growth was minimised reducing the production (SCHROEDER, 1981). On the other hand, low temperature could increase the rate of utilisation of protein of mulberry leaves (SHEN, 1986) resulting in enhanced production.

The correlation reusults (Table 2) revealed that most of the abiotic factors studied had negative correlation with larval duration and coocoon yield. Correlation coefficeint (r) values for larval duration with maximum temperature, minimum temperature and relative humidity were significant showing strong negative correlation. For cocoon yield, only maximum temperature had shown significant r-value while other factors have non-significant r-values. It appears that the temperature above optimum limit (23° - 28°C) had a direct bearing on the cocoon yield while the larval duration could be influenced by humidity as well. Monthly values of humidity were within the optimum limit (70–85%) for silkworm rearing. It could be concluded that thatched mud house was best for maximising the cocoon production followed by tiled house and RCC building under the farmers' practices in Tamil Nadu where lower temperature favoured silkworm growth and cocoon production especially during the summer season when mean monthly temperature outside the rearing house was as high as 40°C. But thatched mud house enhanced the larval duration by about one

TABLE 1. Larval duration and cocoon yield of hybrid silkworm ('PM' × 'NB$_4$D$_2$') under diffferent types of rearing houses during 1987–1989 in Tamil Nadu.

Month	Larval duration (days)				Cocoon yield (kg/100DFLs)				Maximum T (°C)			Minimum T (°C)			RH %		
	Mud-wa-ll that-ched house	Tiled house	R C C house	Mean	Mud-wa-ll that-ched house	Tiled house	RCC house	Mean	Mud-wa-ll that-ched house	Tiled house	RCC house	Med-wa-ll that-ched house	Tiled house	RCC house	Mud-wa-ll that-ched house	Tiled house	RCC house
January	25.8	28.2	27.0	27.0	45.90	39.65	30.80	38.78	24.8	27.1	25.8	22.1	24.0	20.8	62.5	59.2	60.4
February	27.3	27.0	26.3	26.9	42.84	37.27	42.70	40.94	31.8	31.8	28.8	24.6	24.9	22.7	56.5	58.4	61.2
March	26.3	26.1	24.5	25.6	40.06	32.98	27.92	33.65	30.6	31.6	33.8	27.9	27.8	27.7	54.8	54.5	55.5
April	25.2	25.5	25.0	25.2	34.74	32.57	27.52	31.52	33.6	33.8	38.0	28.6	28.8	28.6	61.5	61.1	62.5
May	27.1	25.5	24.3	25.6	38.71	28.73	32.25	33.23	33.4	34.0	35.8	29.1	29.0	29.0	63.5	64.2	67.6
June	26.8	25.8	25.0	25.5	34.82	35.13	21.00	30.32	32.8	33.1	36.2	28.8	28.1	39.8	65.6	65.5	68.5
July	25.8	26.2	25.5	25.8	46.39	34.56	32.46	37.80	30.8	31.1	34.0	27.4	27.1	27.1	73.3	71.9	72.0
August	26.0	25.8	23.3	25.0	43.76	38.28	31.15	37.73	32.6	31.4	33.2	28.0	27.2	26.5	72.6	75.8	73.4
September	25.9	26.2	25.1	25.7	30.75	44.87	21.05	32.22	33.40	31.8	34.3	24.1	26.1	23.8	68.5	70.0	68.9
October	26.1	26.1	24.3	25.5	42.03	36.30	38.30	38.88	30.0	30.1	32.0	24.1	24.1	23.7	74.2	78.2	75.3
November	28.0	28.3	26.4	27.6	41.84	35.80	31.50	36.38	28.6	29.2	31.7	23.2	23.1	23.1	68.4	73.4	70.2
December	27.9	27.9	24.8	26.8	46.56	38.44	34.61	39.87	26.8	29.2	30.1	21.7	21.0	22.6	68.6	72.0	75.4
Mean	26.8	26.1	25.3	26.0	40.70	36.22	31.08	35.94	30.9	31.2	32.8	25.8	25.9	25.5	65.8	67.0	67.6

C D at 5%

Source of variatiion	*Larval duration*	*Cocoon yield*
Rearing house	0.47	3.91
Months	0.94	5.63
Rearing houses × Months	Non- significant	Non-significant

Data compiled from rearing of 33,820 DFLs.

TABLE 2. Relationship of abiotic factors with larval duration and cocoon yield of silkworm *Bombyx mori*.

Abiotic factor	Mean values	Correlation coefficient (r) value	
		Larval duration	Cocoon yield
Maximum temperature (°C)	31.6	–0.58**	–0.35*
Minimum temperature (°C)	25.7	0.47**	–0.18
Temperature variation (°C)	5.8	–0.32	–0.05
Relative humidity (%)	66.8	–0.40*	0.14
Larval duration (days)	26.1	—	0.16
Cocoon yield (kg)	37.83	—	—

* Significant at $p = 0.05$. ** significant at $p = 0.001$.

day as compared to that in tiled house and by 1.5 days as compared to RCC building. The larval duration is a scale for mulberry leaf consumption hence both the larval duration and cocoon yield are to be considered for the weightage of suitability of rearing house.

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Entomon 1991 Vol. **16** No. 3 pp. 213 to 216

EVULATION OF A *BACILLUS SPHAERICUS* FORMULATION, SPHERIFIX™ FOR THE CONTROL OF MANSONIOIDES LARVAE

G. RAJENDRAN, S. SABESAN, M. KUPPUSAMY & K. BALARAMAN
Vector Control Research Centre, ICMR, Pondicherry, India 605 006

(*Received* 30 *June* 1990)

A *Bacillus sphaericus* Meyer and Neide formulation namely, Spherifix™ was evaluated for the control of mansonioides larvae in highly polluted coconut husk retting ponds. The formulation was applied at 5 kg and 10 kg active ingredient (ai) per hectare and more than 90% reduction in larval density was achieved on the 9th and 3rd days, respectively. However, between 9th and 51st days after application, the percentage reduction observed for the two dosages was always more than 90%. The data indicate that Sphreifix has released effective dosage of the ai near the larval feeding zone in a slow and sustained manner for a prolonged period.

(*Key words*: *Bacillus sphaericus*, Spherifix, mansonioides, larval control)

INTRODUCTION

Mansonioides mosquitoes, the vectors of Brugian filariasis are dependent on aquatic weeds for respiration and therefore breed in close association with them. Due to this obligatory association, the larval stages rarely move away from the root zone of weeds and conventional larvicides applied to the breeding sites are not that effective. Control of mansonioides larvae has so far been confined to the use of source reduction method viz., removal of aquatic host plants. In certain instances, formulations of *Bacillus thuringiensis* var. *israelensis* (Berliner) de Barjac (FOO & YAP, 1983) and *Bacillus sphaericus* Meyer and Neide (PRADEEPKUMAR *et al.*, 1988) have also been tried. In the present paper the results of evaluation of a slow release formulation of *B. sphaericus* for the control of mansonioides larvae are reported.

MATERIALS AND METHODS

Spherifix™, a floating type formulation of *Bacillus sphaericus* developed by the Vector Control Research Centre (VCRC), was used in this study. It consists of alginate encapsulated *B. sphaericus* in the form of granules packed in slitted floating polyethylene vials (500 mg of active ingredient (ai) /vial).

The target sites chosen for this study were ponds (21–92 m^2 in size) located in coconut plantations. These were used for retting coconut husks. They were heavily infested (725/0.3 m^2) with aquatic weeds such as *Pistia*, *Salvinia* and *Eichhornia* and the water was highly polluted (86 mg/l suspended solids; 119 mg/l dissolved solids). Twelve such ponds having more or less uniform density of the immatures (larvae and pupae) of mansonioides were selected. Four ponds each were treated with AS Spherifix at the rate of 5 kg and 10 kg ai/ha and another set of four were left untreated.

All the ponds were monitored for the density of immatures (I–IV instar larvae and pupae) prior to and after the application of Spherifix. The density of immatures present at a given time was monitored as the method of FOO & YAP (1983) and expressed as mean number/0.3 m^2. Simultaneously, water and dead larval samples

were collected from the experimental sites and examined for the presence of *B. sphaericus* as per standard procedures.

RESULTS

Control ponds: In the untreated control sites larval density was 160 and that of pupae was 1.80 during first 30 days (pre-treatment period). During next 51 days (post-treatment period) the mean larval density was 160 and that of pupae was 1.39.

Test Ponds (5 *kg ai/ha*): The pre-treatment larval density in this group was 206 and observations made after 24 h of application showed a reduction of 50% (Fig. 1). This increased further to 96% by 9th day. Thereafter, till 51st day post-treatment the reduction fluctuated between 95 and 100%. The mean pupal density was 1.79 during the pre-treatment period which got reduced to 0.56 during the post-treatment period.

Test ponds (10 *kg ai/ha*): The pre-treatment observations (Fig. 1) in these ponds showed the continuous presence of larvae and the density was 107. Application of Spherifix at this dosage has resulted in a reduction of 74% in the larval density within 24 h. It got reduced further to 98% by 3rd day and from there upon till 51st day the percentage reduction varied between 85 and 100. The density of pupae was 1.18 during the pre-treatment period and this got reduced to 0.17 after the treatment.

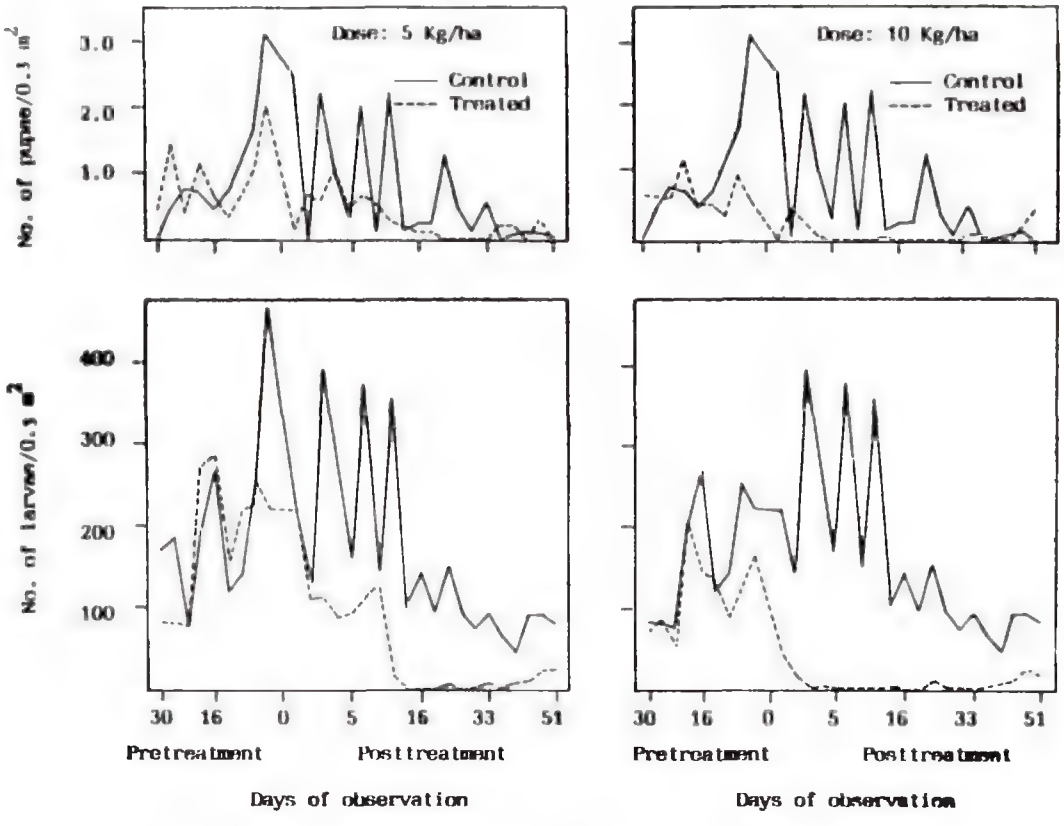

Fig. 1. Effect of *Bacillus sphaericus* on the breeding of mansonioides.

Examination of larvae and water collected from Spherifix treated sites showed the presence of *B. sphaericus*. Similar samples from untreated sites and from treated sites collected during the pretreatment period did not show the existence of native population.

The data showed that the *B. sphaericus* formulation, Spherifix caused significant reduction in the immature density within 24 h of application. At the dose of 5 kg ai/ha, it had taken 9 days to achieve 96% reduction whereas at 10 kg ai/ha, it had taken only 3 days to achieve a reduction of 98%. However, no significant difference in percentage reduction of larval density was observed from 9th day onwards between the two dosages applied. This indicated that at the lower dosage (5 kg ai/ha) the slow release formulation has taken 9 days to release optimal level of active ingredient (spores) whereas at the higher dosage (10 kg ai/ha) the optimal level of release was effected in 3 days. But, once the optimal level of spores were released, the formulation was able to sustain it even at the lower dosage.

DISCUSSION

Foo & Yap (1983) reported that an EC formulation of *B. t.* var. *israelensis* caused distinct reduction in the larval density of mansonioides at dosages greater than 5.7 kg/ha. Lacey *et al.* (1984) observed 30 days of residual activity in laboratory experiments for a pellet formulation of *B. spahericus*. Pradeepkumar *et al.* (1988) showed that a briquette formulation of *B. sphaericus* could exert residual activity against Mansonioides larvae for 31 days. In laboratory studies, this formulation was found to release optimal level of the ai to casue 95–100% larval mortality for the first 15 days (Kuppusamy *et al.*, 1989). But during the next 13 days it was observed to release the ai several folds higher than the optimal level due to rapid distintegration of the briquette. In another study a flowable concentrate of *B. sphaericus* 2362 at 10 kg ai/ha, was found to exert complete control of *Culex quinquefasciatus* Say breeding in cess pools upto 5–6 weeks (Lacey *et al.*, 1988). Similarly the larvicidal activity of the *B. sphaericus* 1593–4 was found to last for 16 days at the dose of 10 kg ai/ha and over a month at the dose of 50 kg ai/ha (Obeta, 1986).

From the data it is inferred that the *B. sphaericus* formulation, Sherifix which is a modification of the one reported earlier (Kuppusamy *et al.*, 1989) has caused substantial reduction in larval density within 3–9 days of application and maintained the same level of pressure on the immature density upto 51 days. Thus it has released optimal level of active ingredient in a slow and sustained manner in contrast to the erratic release by the briquette formulation (Pradeepkumar *et al.*, 1988). Although there was a delay of 6 days to cause 96% reduction at 5 kg ai/ha, this dose itself was sufficient to exert the required pressure on mansonioides larvae for the next 42 days. Use of Spherifix at this dosage will be more economical compared to briquettes which show a residual activity of 31 days at the dose of 15–30 kg ai/ha (Pradeepkumar *et al.*, 1988). Spherifix has distinct advantages over the other *B. sphaericus* formulations also evaluated by Obeta (1986) and Lacey *et al.* (1988) wherein *C. quinquefasciatus* breeding was reported to have been controlled for 4–6 weeks at the dosages of 10–50 kg ai/m^2.

These observations lead to conclude that it is possible to control *Mansonioides* larvae cost-effectively using Spherifix as it needs to be applied once in 6 or 7 weeks compared to other types of formulations which have to be applied once in 1–4 weeks.

ACKNOWLEDGEMENTS

The authors are grateful to Dr. P. K. RAJAGOPALAN, Director, Vector Control Research Centre for valuable suggestions and encouragement. This investigation received financial support from the UNDP/ World Bank/WHO Special Programme for Research and Training in Tropical Diseases, WHO, Geneva.

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Entomon 1991 Vol. 16 No. 3 pp. 217 to 221

STUDIES ON THE INCIDENCE OF DATE PALM SCALE, *PARLATORIA BLANCHARDI* (TARG.) IN WESTERN RAJASTHAN

R. SWAMINATHAN & S. K. VERMA[1]
S.K.N. College of Agriculture, Jobner (Rajasthan), India

(*Received* 28 *October* 1990)

Incidence of *Parlatoria* scale on date palm was studied in arid western Rajasthan at Bikaner. Infestation set in December onwards on pinnae from basal tissues upwards and reached its peak in October. Older leaves and upper leaf surfaces near pinnae were preferred but tips invariably remained free from infestation. During May – June, infestation declined on pinnae but was concentrated on floral parts and on berries. Crawlers were most active during February – April and their numbers declined rapidly thereafter. Incidence of the scales on pinnae had significantly negative correlation with average maximum temperature and relative humidity. Cv 'Khadrawy' and 'Medjool' were susceptible and 'Zahdi' and 'Migraf' were tolerant to scale infestation. *Pharoscymnus horni* was recorded as the dominant predator, feeding on 27 scales/beetle/24 h.

(*Key words*: date palm scale, *Parlatoria blanchardi*, preference, leaf surface)

INTRODUCTION

Scale *Parlatoria blanchardi* (Targ.) (Diaspididae, Homoptera), the most important insect pest of date palm, is probably indigenous to Iraq (CALCAT, 1959). In India, it was first observed in 1970 at Abohar in Punjab (BATRA & SOHI, 1974) and then from western Rajasthan (SACHAN, 1976). Although BUTANI (1975) regarded it only as a minor pest, its heavy incidence causes a general decline in the growth of the palms and poor quality of berries.

MATERIALS AND METHODS

Incidence studies of the *Parlatoria* scales on date palm were undertaken in 1987 at the Date Palm Research Centre, Bikaner throughout the year on two susceptible cultivars viz., 'Suria' and 'Khadrawy'. During the last week (day 25–30) of every month, five leaves were selected at random from the lower and middle leaves of three palms of near equal age (about 5 years) and two pinnae were selected at random from each of the five leaves. Presence of crawlers, pupae and female adults was recorded and countings were done under a dissecting binocular. The crawlers were detected by gently disturbing or removing the scale cover with a pin. The samples were maintained on fresh pumpkin slices in a B. O. D. incubator at 28° ± 2°C. Adult males were counted on emergence from these samples.

Mounts of crawlers and adults were made in a medium containing polyvinyl alcohol 12 g, chloral hydrate 100 g, lactic acid 12 ml, liquid phenol 12 ml, glycerol 10 ml and distilled water 100 ml.

Varietal screening was done in October, before leaf removal and setting of winter, when all the palms got fully exposed to maximum natural infestation.

RESULTS AND DISCUSSION

The incidence of scales on palms occurred throughout the year but the pest was more

[1]Sciantist Selection Grade, CAZRI, Jodhpur 342003, India.

active from September onwards when maximum numbers of adults and crawlers were observed. Population trends of scales on 10 cm pinnae of two susceptible varieties of date palm viz., 'Khadrawy' and 'Suria' (Table 1) showed great variations in different months but still, a general trend of decrease in infestation from March to June was discernible. AL-HAFIDH *et al.* (1981) mentioned that in Iraq, the infestation started in April. SACHAN (1976) reported the period of attack as December to March coinciding with the period of bloom. In fact, with the onset of winters, only the number of crawlers goes on decreasing with a fall in temperature. Thus, in western Rajasthan, infestation sets in well before mid-December. There are many overlapping generations in a year and most nymphs develop into females. Crawlers were more abundant on cv 'Suria' during February to March and on 'Khadrawy' crawlers were more abundant during April. No crawlers could be detected during June to August and only a few dead crawlers were seen during December. SHARIF & WAJIH (1983), however, reported crawlers moving and settling on palms even during the coldest parts of the year in Pakistan. Presence of crawlers from September to October and again from February to May indicated periods of activity of the spread of scales.

Eggs, as well as crawlers, were pinkish red in colour and the incubation period varied from 3 to 10 days (cf. SHARIF & WAJIH, 1983). ABDUL-AHAD & JASSIM (1983) recorded the colour of scales at I moult as green. Males emerging from pupae were observed to have a longevity of 3 to 4 days. These were smaller (0.685 – 0.690 mm long) than the females (0.985 to 0.99 mm)

TABLE 1. Population of *Parlatoria blanchardii* on 10–cm pinnae of two date palm cultivars.

Month	cv 'Suria'					cv 'Khadrawy'				
	Av. No. of scales				*Presence of crawlers	Av. No. of scales				*Presence of crawlers
	1	2	3	Mean		1	2	3	Mean	
Feb.	210	186	132	176	+ +	165	212	231	202.6	+
Mar.	256	296	340	297.3	+ +	146	182	130	153.6	+
Apr.	195	186	173	184.6	+	186	210	214	202.6	+ +
May	175	162	105	143.3	+	121	89	82	97.3	+
Jun.	75	72	18	55	—	37	27	29	31	—
Jul.	18	27	32	25.6	—	22	81	46	49.6	—
Aug.	87	77	97	86.6	—	16	15	18	16.3	—
Sep.	320	315	173	269.3	+	49	51	58	52.6	+
Oct.	296	342	256	298	+	87	35	85	69	+
Nov.	186	132	146	154.6	—	85	96	27	69.3	—
Dec.	263	95	112	156.6	x	162	164	58	134.6	x

*Crawlers: Live crawlers present +, frequently found + +
Live crawlers absent —, dead crawlers found x

with scale cover, 0.80 to 0.82 mm without scale cover). In both the sexes, maximum width was 0.65 mm, it being only 0.62 mm in females without scale cover. The crawlers (with tubercles) measured 0.395 to 0.49 mm in length.

The attack of scales on uninfested leaves ususally started from their basal tissues and tended to be more congregated on main rachis, mid-rib and veins of the pinnae. Upper surface of leaf was preferred to lower one. The tips of leaves were invariably free from the scales, although *Parlatoria* scale is reported to be capable of spreading over all surfaces of the foliage (SHARIF & WAJIH, 1983). BATRA & SOHI (1974) also reported that the sacle spreads from base of leaf stalk to entire leaf in Abohar (Punjab). Older leaves towards base of the plants were preferred more than the upper leaves. DABBOUR (1981) also mentioned that *Parlatoria* scales preferred the lowest leaves, with minimum on top of the trees. However, the difference in the number of scales on central and lowermost leaves was reported to be non-significant.

The number of scales on pinnae was particularly low during summer months of May and June. AL-HAFIDH *et al.* (1981) found high density of scales to occur during May - June. In the present study, during May to July, crawlers, nymphs, pupae and female imagin were found also on fruit stalks, strands and on the proximal end of berries.

TABLE 2. Weather parameters at Bikaner and correlation of the number of scales/pinna on date palm cv 'Suria' and 'Khadrawy"

Month	Av. Temperature			Av. Relative humidity		
	Min.	Max.	Mean	08.00 h	16.00 h	Mean
Jan.	6.22	23.50	14.86	70.22	28.16	49.19
Feb.	10.32	27.88	19.10	64.35	17.82	41.08
Mar.	18.63	31.59	25.11	60.61	20.29	40.45
Apr.	21.94	38.00	29.97	31.10	10.17	20.63
May	23.63	38.10	30.86	55.16	25.51	40.33
Jun.	28.10	41.16	34.63	58.64	26.83	42.73
Jul.	28.95	40.05	34.50	68.16	32.74	50.45
Aug.	27.94	40.51	34.22	70.25	34.25	52.25
Sep.	25.00	39.06	32.06	58.93	25.36	42.14
Oct.	19.43	37.70	28.56	47.00	15.09	31.04
Nov.	10.50	31.60	21.05	52.50	27.20	39.85
Dec.	4.87	25.07	14.97	59.92	23.28	41.60
'r' value for cv						
Suria	—0.32	—0.556*	—0.305	—0.370	—0.632*	—0.587
Khadrawy	—0.278	—0.62*	—0.503	—0.423	—0.767	—0.590*

(* Significant at $P = 0.05$)

The numbers of scales on pinnae were observed to have significantly negative-correlation with the temperature and relative humidity (Table 2).

On the basis of the average number of scales per pinna, 15 cultivars of date palm were screened against the *Parlatoria* scale in October, when the numbers of scales were maximum. The cultivars were categorized as susceptible, moderately susceptible and tolerant (Table 3). The popular varieties 'Khadrawy' and 'Medjool' turned out to be susceptible whereas 'Zahidi' and 'Migraf' were tolerant. 'Halawy', 'Barhee' and 'Shamran' were moderately susceptaible. AL-HAFIGDH *et al.* (1981) also recorded 'Halawy' and 'Barhee' less susceptible than 'Chib chab'.

Some beetles were observed to predate upon the *Parlatoria* scales and these were determined to be *Chilochorus renipustulatus*, *Menochilus sexmaculatus* and *Pharoscymnus horni*. *P. horni* was observed to be more numerous and active than others and, therefore, observations were also recorded on the predatory efficacy of this beetle (Table 4). It ranged from 12 to 45 scales per beetle in 24 h, the overall mean predation being 27 scales per beetle.

TABLE 3. Screening of date palm cultivars against *Parlatoria blanchardii* on the basis of average number of scales/ pinna.

Susceptible (>500 scales)	Moderately susceptible (100 – 500 scales)	Tolerant (<100 scales)
Khadrawy	Halawy	Zahidi
Gizaz	Barhee	Medini
Sewi	Bint Aisha	Khalas
Suria	Shamran	Migraf
Medjool		Abdul Rehman
		Umshok

TABLE 4. Predation of *Parlatoria* scale by *Pharoscymnus horni* on date palm at Bikaner.

Sample	No. of scales on pinna		No. of scales predated	
	Before predation	After 72 h	Total in 72 h	Mean for 24 h
1.	550	480	70	23.3
2.	45	6	39	13
3.	792	656	136	45.3
4.	138	18	120	40
5.	382	346	36	12
6.	381	272	109	36.3
7.	276	187	89	29.66
8.	145	84	61	20.3

ACKNOWLEDGEMENTS

Authors are thankful to the Director of Research, Rajasthan Agricultural University, Bikaner for the facilities of observations at the Date Palm Research Centre, Bikaner. Thanks are due also to Dr B. B. VASHISHTHA, Horticulturist, CAZRI, Jodhupur for valuable suggestions and help in the study.

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Entomon 1991 Vol. 16 No. 3 pp. 223 to 227

LABORATORY TECHNIQUE FOR MASS MULTIPLICATION OF PINK BORER, *SESAMIA INFERENS* WALKER (NOCTUIDAE: LEPIDOPTERA)

S. EASWARAMOORTHY, H. DAVID & M. SHANMUGASUNDARAM
Sugarcane Breeding Institute, Coimbatore, India

(*Received* 23 *May* 1990)

An artificial diet based on Kabuligram and sugarcane shoot powder for mass rearing of the pink borer, *Sesamia inferens* Walker has been developed. The pink borer has been successfully multiplied on the diet for more than fifteen generations at Sugarcane Breeding Institute, Coimbatore. The total life cycle is completed in 40.2 to 63.3 days during different generations. The larvae and adults produced are normal. The mean fecundity is 54.73 eggs/female. The production cost works out to be 0.35 paise per larva. The larvae are used for rearing Tachinid parasite, *Sturminopsis inferens* Tns.

(*Key words:* artificial diet, mass-rearing, pink borer, *Sesamia inferens* fifteen generations)

INTRODUCTION

The pink borer, *Sesamia inferens* Wlk. is an important pest of finger millet (*Eleusine coracana* Gaeytn) and it also infests several other graminaceous crops including sugarcane (*Saccharum* spp.), sorghum (*Andropogon sorghum* Brot.) wheat (*Triticum aestivum* L.) and rice (*Oryza sativa* L.). It is the most suitable host for the multiplication of the Tachinid fly, *Sturmiopsis inferens* Tns., the principal parasite of shoot borer, *Chilo infuscatellus* Snell. (DAVID *et al.*, 1980). Continuous availability of pink borer in the laboratory is necessary to multiply the parasite in large numbers. As the incidence of pink borer on ragi and sugarcane is very rare around Coimbatore, there is a need to develop an artificial diet for the multiplication of this borer. Chatterji *et al.* (1969) could successfully rear *S. inferens* on an artificial medium based on wheat germ. Later, QURESHI *et al.* (1972) mass reared the insect on artificial diet containing rice stem powder. The earlier diet developed at Commonwealth Institute of Biological Control, Bangalore (NAGARAJA, personal communication) when tried, showed poor growth of young larvae and also very high mortality. So attempts were made to develop a suitable diet for the mass multiplication of pink borer and the details are presented in this paper.

MATERIALS AND METHODS

i) *Nucleus culture:* The initial laboratory culture of pink borer was established in the laboratory from field collected larvae. They were reared on cut stems of sugarcane or ragi (5–6 cm length) split open at one end and kept inside plastic boxes (7.0 cm dia × 7.5 cm height) provided with filter paper at the bottom to absorb moisture. The filter paper and shoot bits were changed once in two days. The pupae collected were disinfected with 10% alcohol, washed in distilled water and placed in an emergence box (33 × 25 × 27 cm) for the emergence of moths. Freshly emerged male and female moths were released in an egg laying cage (65 cm × 55 cm × 49.5 cm). The cage has been provided with muslin cloth on three sides and top, with a sliding glass door in the front. Cut sugarcane plants (45 to 60 days old) were kept inside the cage in vertical

position. The cut end of the plants were wrapped with moist cotton swab to prevent desiccation and the leaf sheaths were loosened a little to facilitate oviposition. Four days after the release of moths, eggs were collected from these plants and fumigated at 20°C with 0.1 ml of 10 percent formalin for 6 hours and then transferred to a plastic container for hatching.

ii) *Artificial diet:* Different combinations of the ingredients were tried, taking the diet developed for internode borer, *Chilo sacchariphagus indicus* (Kapur) by MEHTA & DAVID (1978) as the basic one. The final diet formulated was given in Table 1. This diet was used for rearing pink borer larvae upto III instar stage.

Preparation:

The ingredients were divided into 3 fractions, A, B, and C as indicated in Table 1. The total water required was divided into two parts 270 and 180 ml. Water, 270 ml and fraction 'A' were added to the blender and mixed thoroughly for 3 minutes. Fraction 'B' was boiled at 90°C along with 180 ml of water and then cooled to 70°C. This was added to fraction 'A' which was transferred to a clean and sterilised plastic basin. Both fraction 'A' and 'B' were mixed thoroughly and then fraction 'C' was added in small quantities with thorough mixing. The diet was transferred to sterilised glass bottles (6.3 cm dia × 11.2 cm height) at the rate of about 85 g per bottle. The diet bottles were covered with muslin cloth immediately and then covered with lids the next day. The diet thus prepared was used upto 3 days for inoculation of larvae.

The neonate larvae were transferred at the rate of 75/diet bottle. The diet was changed once in 10–12 days twice. During the first change, 40 larvae were introduced per bottle and at the second change, 25 larvae per bottle. At each change, the larvae were disinfected with 10% alcohol and washed thoroughly with distilled water to avoid contamination.

TABLE 1. Composition of diet 1.

	Ingredient	Weight in g
	Fraction A	
1.	Kabuligram flour	60.0
2.	Casein	50.0
3.	Ascorbic acid	10.0
4.	Yeast tablets	22.5
5.	Sucrose	22.5
6.	Methyl parahydroxy benzoate	2.0
7.	Sorbic acid	1.0
8.	Hostacycline	1.0
9.	Multivitaplex capsules (2 Nos.)	1.0
10.	Vitamin E (1 No.)	0.1
11.	Saffola oil	5.0 ml
12.	Formalin 40%	1.0 ml
	Fraction B	
1.	Agar-agar	10.0
	Fraction C	
1.	Sugarcane shoot powder*	75.0
	Distilled water	450 ml

* Sugarcane shoot powder was prepared by chopping young sugarcane shoots (45–60 days old) into small bits, drying it for 3–4 days in the hot sun then powdering it in a Wiley mill using 60 mesh sieve.

When the larvae moult into fourth instar they were transferred to the diet II developed at CIBC, the composition of which is given in Table 2.

Preparation of the diet was done as indicated for diet 1 by adding 600 ml of water with fraction A and 500 ml with fraction B. The diet prepared was poured to a sterilised

TABLE 2. Composition of diet 2.

	Ingredient	Weight in g
	Fraction A	
1.	Kabuligram flour	100.0
2.	Milk powder	40.0
3.	Sucrose	60.0
4	Yeast tablets	20.0
5.	Methyl parahydroxy benzoate	2.0
6.	Sorbic acid	1.0
7.	Ascorbic acid	6.5
8.	Cholestrol	2.0
9.	Salt mixture No. 2	2.0
10.	Vitamin E (1 No.)	0.2
11.	Maize flour	100.0
12.	Hostacycline	2.0
13.	Linseed oil	3.0 ml
14.	Formalin 40%	4.0 ml
	Fraction B	
1.	Agar-Agar	23.0
	Distilled water	1100.0 ml

plastic basin to a height of 2 cm. The solidified diet was cut into pieces of required size and transferred to tubes (10 cm × 2.5 cm dia) sterilized with alcohol.

The fourth instar larvae collected from diet I were transferred at the rate of 3 per tube containing the diet piece. The pupae as and when formed were collected. They were disinfected in 10% alcohol, washed with distilled water and dried over filter paper. The pupae were transferred to Petri dishes provided with filter paper at the bottom and kept inside emergence boxes.

The laboratory multiplication was done at room temperature (28±2°C) and at 60–70 percent relative humidity. Observations were made on the life cycle, larval survival, pupation, moth emergence, sex ratio, fecundity, fertility and adult longevity.

RESULTS AND DISCUSSION

The details of data collected for six generations on egg, larval and pupal period and total life cycle is given in Table 3. The mean egg period varies from 5.5 to 8.2 days, larval period from 28.1 to 47.5 and pupal period from 6.2 to 12.7 days respectively in different generations. Earlier, KRISHNAMURTHI & USMAN (1952) reported 5–9, 22–61 and 10–14 days as egg, larval and pupal period, respectively under natural conditions. It clearly indicates that there is no prolongation in the life cycle, when the pink borer is reared on the artificial diet. The variation in the duration of different stages between generations may be attributed to variation in the laboratory temperature, as the fifth and sixth generations are reared during winter months.

The total life cycle is completed in 40.2 to 63.3 days during different generations and it is comparable with that of earlier reports of KRISHNAMURTHI & USMAN (1952). The neonate larvae settle for feeding on diet I within half an hour after release and similarly fourth instar larvae on diet 2 under room temperature. The suitability of the diet for larval development is also indicated by the weight of the larvae and pupae (Table 3). The average weight of full grown larvae varied from 197.3 to 229.6 mg and freshly formed male and female pupae from 86.6 to 104.7 and 121.1 to 153.6 mg respectively.

The details of number of moths released in each generation, fecundity, fertility, survival and sex ratio are given in Table 4. A total of 3458 female and 3317 male moths were released during the five generations. The females laid 1,58,811 eggs with a mean

TABLE 3. Life cycle and larval and pupal weights of *S. inferens* in different generations.

Generation	Average duration of different stages (in days)				Mean weight of different stages (in mg)		
	Egg	Larval	Pupal	Total life cycle	Larval	Pupal	
						Male	Female
I	5.5 (5–6)	28.5 (28–31)	6.8 (6–8)	41.5 (40–43)	224.62	103.98	137.37
II	5.2 (5–6)	28.1 (28–30)	6.2 (6–7)	40.2 (40–41)	229.62	104.66	153.60
III	5.8 (5–6)	35.4 (35–37)	7.5 (7–8)	42.8 (45–48)	227.12	103.30	130.15
IV	6.8 (6–7)	40.7 (39–42)	8.6 (7–9)	53.5 (51–56)	212.21	95.63	124.70
V	7.5 (7–8)	41.8 (44–47)	8.9 (10–12)	58.7 (58–63)	210.96	94.95	122.92
VI	8.2 (7–9)	47.5 (46–49)	12.7 (11–13)	63.3 (61–65)	197.30	86.60	121.14

Note: Figures in parenthesis are range in days.

TABLE 4. Details of fecundity, fertility, survival, adult emergence and sex ratio in different generations.

Generation	No. of moths released		No. of eggs collected	Mean fecundity	Per cent fertility of eggs	No. of neonate larvae inoculated	No harvested		Total	Percent larval survival	Percent moth emergence	Sex ratio (female: male)
	Female	Male					Larvae	Pupae				
I	150	146	2622	17.96	78.19	2050	0	565	565	27.56	90.09	1:0.82
II	279	230	28088	122.12	76.55	21502	4935	2399	7334	34.11	89.45	1:0.86
III	1154	992	59619	60.09	70.86	42244	10188	2214	12402	29.36	86.27	1:0.97
IV	968	942	49875	52.95	84.85	42319	7392	2067	9459	22.35	92.60	1:0.90
V	907	1007	18607	20.52	85.51	15910	2881	1869	4750	29.86	92.88	1:0.77
Total/ Mean	3458	3317	158811	54.73	79.19	124025	25396	9114	34510	28.65	90.25	1:0.86

fecundity of 54.73. Earlier, KRISHNAMURTHI & USMAN (1952) reported 62 to 140 eggs per female with an average of 117. The fertility of eggs varied from 70.86 to 85.51 in different generations with a mean of 79.19 and is comparable with the fertility of eggs (81.6 – 89.2) obtained from moths reared on natural food (LINGAPPA, 1978). During the five generations, 1,24,025 neonate larvae were inoculated on artificial

diet I and out of the 34,510 full grown larvae obtained from diet II, 25,396 were used for laboratory multiplication of the Tachinid parasite, *Sturmiopsis inferens* Tns. The mean percent survival of larvae was 28.65. The percent moth emergence ranged from 86.27 to 92.88 in different generations with a mean of 90.26. The proportion of female moths was slightly higher in all the generations and the sex ratio was 1 : 0.8 (female : male).

This modified diet has been found to be extremely useful in maintaining a stock culture of *Sesamia inferens* for over fifteen generations. The insect completes its life cycle without any prolongation on the artificial diet. Similarly, there is no reduction in the size of the larvae and pupae. Moths obtained are fecund and there is no degeneration of the culture. Maintenance of *S. inferens* culture throughout the year in the laboratory is very useful in the large scale multiplication of the parasite *Sturmiopsis inferens*. The cost of production of one larva on artificial diet accounts to 35 paise only.

ACKNOWLEDGEMENTS

The authors are thankful to Dr. K. MOHAN NAIDU, Director, Sugarcane Breeding Institute for the facilities provided.

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Entomon 1991 Vol. 16 No. 3 pp. 229 to 232

USEFULNESS OF FISH OIL ROSIN SOAP IN THE MANAGEMENT OF WHITEFLY AND OTHER SAP FEEDING INSECTS OF COTTON

K. NATARAJAN, V. T. SUNDARAMURTHY & P. CHIDAMBARAM
Central Institute for Cotton Research Regional Station, Coimbatore, India 641 003

(*Received* 12 *August* 1990)

Three natural products and seven insecticides were evaluated against cotton whitefly, thrips and aphids. Fish oil rosin soap, neem oil and mineral oil effectively suppressed the whitefly population build up, whereas monocrotophos and methamidophos led to increased whitefly build up. Fish oil rosin soap was also effective against cotton thrips and aphids. Among the insecticides triazophos, amitraz and phosalone were effective to whitefly. The natural products were least harmful to the whitefly parasite.

(*Key words:* cotton, natural products, fish oil rosin soap, insecticides, whitefly, thrpis, aphids, control)

INTRODUCTION

Whitefly, *Bemisia tabaci* Gennadius is a serious pest of cotton and other crops in many countries and outbreaks appear to have increased since the use of insecticides (GREATHEAD & BENNET, 1981). The problems associated with the indiscriminate use of insecticides in cotton ecosystem have been well documented (EVELEENS, 1983; SUNDARAMURTHY & BASU, 1985). In India, development of specific method of control for this pest was not warranted as its low level of population did not pose any problem (REDDY *et al.*, 1985). This situation suddenly changed leading to unabated escalation of population in several parts of India and repeated application of conventional insecticide failed to reduce the population explosion (BASU, 1986).

Researchers are now concentrating to identify effective and safe chemicals with less hazards to the environment and non-target organism including beneficial insects, livestock and man. The present paper deals with the investigations on the effectiveness of certain natural products (fish oil rosin soap: FORS, mineral oil and neem oil) and certain insecticides against whitefly, aphid (*Aphis gossypii* G) and thrips (*Thrips tabaci* Lind and *Scirtothrips dorsalis* Hamp).

MATERIALS AND METHODS

Two field experiments were conducted during 1986–1987 winter and summer seasons using the cotton cultivar 'LRA 5166' (*Gossypium hirsutum* L). Three natural products (viz., fish oil rosin soap, courtesy, Kerala Soap Factory, Calicut) neem oil, mineral oil and 7 insecticides (Table 1) were evaluated during winter season. Two natural products and six insecticides (Table 2) were tested in summer 1987 season. The chemicals were sprayed thrice 90, 100 and 115 days after sowing in winter season and on 40, 50 and 65 days after sowing in summer season. Prior to these the crop was protected from other sucking insects by applying methyl demeton 0.05%. Chemicals were applied early in the morning using hand compression sprayer and spray fluid used was 750 l/ha. In general bollworm incidence was low and hence spraying was not done for boll worm control.

TABLE 1. Effect of fish oil insecticidal soap and certain insecticides on the population of whitefly and aphid (1986–1987 winter).

S. no.	Treatments	Whitefly			parasitism (%)	aphids /leaf	bollworm incidence %	yield (q/ha)
		eggs/ sq. cm	nymphs/ leaf	adults/ leaf				
1.	fish oil rosin soap (FORS) 2%	2.4a	18.6a	4.6a	19.4cd	13.8a	19.8a	11.8ab
2.	neem oil 0.5%	2.9ab	20.7ab	5.9bc	15.2cd	31.6a	19.6a	12.0abc
3.	mineral oil 2%	2.4a	20.0ab	7.0bc	14.8bc	19.0a	17.3a	12.6abcd
4.	triazophos 0.07%	3.6ab	17.4a	5.3a	7.7a	70.6b	12.6a	15.8d
5.	amitraz 0.08%	5.6ab	28.1abc	6.1bc	17.2cd	11.9a	17.7a	10.8a
6.	phosalone 0.08%	4.4ab	34.9bc	8.0cd	18.0cd	13.7a	19.3a	12.2abc
7.	endosulfan 0.08%	6.8b	47.1c	6.4bc	16.6cd	16.4a	17.9a	13.2abcd
8.	quinalphos 0.07%	5.3ab	36.5bc	9.9d	9.7ab	44.9a	17.6a	12.6abcd
9.	phosalone 0.07% + FORS 1%	3.3ab	22.7ab	3.3a	14.3bc	14.5a	17.7a	14.6cd
10.	methamidophos 0.08%	23.9c	119.4d	25.7e	8.1a	10.6a	23.6a	11.4ab
11.	monocrotophos 0.08%	25.5c	114.4d	21.8e	7.6a	9.4a	17.4a	15.5cd
12.	untreated check	3.8ab	16.7a	3.6a	21.6d	10.6a	24.8a	9.7a

In a column means followed by the same letter are not significantly different ($P = 0.05$).
Chemicals sprayed on 90, 100 and 115 days after sowing.

The observations on the population of adults were recorded twice on 5 and 10 days after each spray on two terminal leaves of 20 random selected plants. Egg density was assessed a week after second spray (107 days after sowing) from 20 terminal leaves excised from 20 plants. Nymphal population was scanned using binocular microscope in the laboratory from 20 leaves collected from the middle canopy of the plant (5th and 6th leaf from top). Thrips population (both larva and adult) was assessed through binocular microscope from the leaves used for whitefly nymphs observation.

The parasitised nymphs were identified under binocular microscope by noticing the change in the colour of the nymphs and the presence of parasitic grub or pupae in the translucent body of the numph (NATARAJAN *et al.*, 1986).

Aphid population was assessed in the winter trial, 15 days after last spray (130 days after sowing) from 30 leaves at the rate of three per plant (top, middle and bottom) from 10 random selected plants.

The bollworm incidence was assessed by recording the total and affected bolls on retained bolls from 20 random selected plants.

TABLE 2. Effect of fish oil insecticidal soap and certain insecticides against whitefly and thrips (1987 summer).

Treatments	Population per leaf (mean of two observations)	
	Whitefly nymphs	Thrips
1. fish oil rosin soap 2%(FORS)	15.3a	20.7c
2. neem oil 0.5%	18.0a	41.0de
3. triazophos 0.07%	20.1b	23.9c
4. amitraz 0.08%	24.5c	25.7c
5. phosalone 0.08%	37.6d	12.2d
6. endosulphan 0.08%	39.8d	38.3de
7. quinalphos 0.08%	40.8d	37.4d
8. monocrotophos 0.08%	60.6e	4.9a
9. untreated check	17.1a	43.7e

In a column means followed by the same letter are not significantly different ($P=0.05$). Chemical sprayed on 30, 40, and 55 days after sowing.

RESULTS AND DISCUSSION

Significant low level of whitefly population was recorded in fish oil rosin soap (FORS) treated plots in both the experiments. The density of eggs, nymphs and adults in FORS treated plot was 2.6, 18.6 and 4.6 per unit area as compared to 25.5, 111.4 and 21.8 under monocrotophos and 23.9, 119.4 and 25.7 in methamidophos in the first experiment (Table 1). Monocrotophos and methamidophos treatments harboured the maximum number of whitefly population. In the summer experiment also, FORS treated plots harboured minimum population of 15.3 nymphs per leaf followed by neem oil treatment (18.0/leaf) as compared to 60.6 in monocrotophos. FORS when applied with phosalone also resulted in less whitefly population (Table 1). FORS has been earlier reported to be effective against *B. tabaci* (VENUGOPAL-RAO *et al.*, 1990). JALALUDDIN & MOHANASUNDARAM (1989) reported that FORS was effective against coconut scale *Aspidiotus destructor* Sign due to asphyxiation action.

Among the insecticides, minimum whitefly population was in triasophos treatment followed by amitraz and phosalone which is in agreement with the previous reports (PEREGRINE & LEMON, 1986; VENUGOPAL-RAO *et al.*, 1990)

The level of parasitism on whitefly under different treatments varied from 7.6 to 21.6 percent, the highest being in untreated check. The parasites recorded were *Eretmocerus mundus* Mercet and *Encarsia shafeei* Hayat. Among the chemicals maximum parasitism of 19.4 percent was found in FORS followed by phosalone (18.0%), amitraz (17.2%) and endosulfan (16.6) and they remained on par with untreated check. Monocrotophos, triazophos, methamidophos and quinalphos adversely affected the abundance of parasites with 7.6, 7.7, 8.1 and 9.7 percent parasitism respectively.

The population of thrips was reduced to the minimum level of 4.9 per leaf in monocrotophos as compared to 43.7 in untreated check. Thrips population in FORS treatment was 55 percent less than those observed in untreated check (Table 2).

Aphid population after 130 days of sowing indicated that the population density per leaf in FORS treatment was 13.8 and remained on par with other insecticides excepting triazophos which registered the maximum population density of 70.6 per leaf (Table 1).

The bollworm incidence did not vary with the treatments and it varied from 12.6 to 23.6% in different treatments as compared to 24.8% in untreated check.

Seed cotton yield in FORS (11.8 q/ha remained on a par with most of the conven-

tional insecticides like endosulfan, quinalphos and phosalone. Maximum seed cotton yield of 15.8 q/ha was realised from triazophos.

These results indicate that the natural product fish oil rosin soap which gave good control of whitefly, thrips and aphids, can be utilised for the management of whitefly and other sap feeding insects.

ACKNOWLEDGEMENTS

Authors are grateful to Dr. HAYAT, Department of Zoology, Aligarh Muslim University, Aligarh for identification of parasites and to Dr. A. K. BASU, Project Co-ordinator & Head, Central Institute for Cotton Research, Regional Station for providing facilities.

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Entomon 1991 Vol. 16 No. 3 pp. 233 to 235

COMPARATIVE ASSESSMENT OF PYRETHROID-RESISTANCE IN CERTAIN POPULATIONS OF *HELIOTHIS ARMIGERA* HBN. IN ANDHRA PRADESH

G. P. V. REDDY, V. DEVA PRASAD, P. SATYAVANI & M. M. K. MURTHY
Department of Entomology, Agricultural College, Bapatla, India 522 101

(*Received* 28 *October* 1990)

Third instar larvae of gram caterpillar, *Heliothis armigera* Hbn. representing three populations of Guntur (GNT), Kurnool (KNL) and Srikakulam (SKL) districts of Andhra Pradesh, were bioassayed for their susceptibility to three widely used synthetic pyrethroids viz., cypermethrin, decamethrin and fenvalerate. Of the three strains of *H. armigera*, SKL was the most susceptible strain followed by KNL and GNT strains in terms of LC_{50} values. The latter two were compared with SKL strain to register the resistance levels in them. GNT strain was found to have developed 18.7, 7.8 an 9.2 fold resistance and KNL strain 10.5, 4.8 and 6.4 fold resistance to cypermethrin, decamethrin and fenvalerate respectively.

(*Key words*: *Heliothis armigera*, pyrethroid-resistance)

INTRODUCTION

Reported resistance in American bollworm, *Heliothis armigera* Hbn. to insecticides was attributed to excessive use of insecticides, sublethal doses, improper coverage, sub standard chemicals etc. But the actual levels of resistance to widely used synthetic pyrethroids in *H. armigera* populations, particularly in Andhra Pradesh, were not well documented. Recent reports indicated that *H. armigera* population in Andhra Pradesh exhibited resistance to synthetic pyrethroids viz. cypermethrin (DHINGRA *et al.*, 1988; ANONYMOUS, 1988; MC CAFFERY *et al.*, 1989) and fenvalerate (MC CAFFERY *et al.*, 1989).

The present study was conducted during the years 1989-1990 with a view to assess the levels of susceptibility in three populations of *H. armigera* representing Guntur (GNT), Kurnool (KNL) and Srikakulam (SKL) districts of Andhra Pradesh to fenvalerate, decamethrin and cypermethrin. The actual resistance levels were worked out by comparing LC_{50} values of each insecticide for the three strains of the test insect as per the formula suggested by ANONYMOUS (1969).

MATERIALS AND METHODS

Cultures of *H. armigera* representing three locations in Andhra Pradesh (GNT, KNL SKL strains) were raised from field larvae collected individually in glass vials (3.5×2 cm) containing semi-synthetic diet (SHOREY & HALE, 1965) to avoid cannibalism. Larvae were reared through different instars until pupation. Neonate larvae of next generation were released on to tender chickpea plants grown in pots and reared through first and second instars. Newly moulted third instar larvae were used in different bioassays.

The three commercial synthetic pyrethroids selected for the present study were cypermethrin (Ripcord 10 EC), decamethrin (Decis 2.8 EC) and fenvalerate (Fenval 20 EC). Before fixing the doses for final test bracketing procedure was adopted. For each insecticide, different test concentrations were prepared following the serial dilution technique.

Terminals of cotton plant were dipped in the different concentrations of each insecticide separately and dried for 10 minutes. Newly moulted third instar larvae from laboratory-bred cultures of *H. armigera* representing GNT, KNL and SKL strains were allowed to feed on the treated cotton terminals individually in plastic vials (15 × 10 cm). For each concentration, 20 larvae were used. The control larvae were allowed to feed on water treated terminals. Observations were recorded after 24 h of treatment. Percent mortality was calculated and corrected based on Abbott's formula whenever mortality in control was observed. The data on dosage mortality response of third instar larvae of the three strains to the three insecticides were subjected to probit analysis according to FINNEY (1964).

RESULTS AND DISCUSSION

The data on the dosage mortality response in third instar larvae of the three strains of *H. armigera* to the three pyrethroids are presented in Table 1. The Chi-square values were indicative of good fit of probit regression lines in all the bioassays. Comparison of LC_{50} values of each insecticide for the three strains indicated that SKL strain manifested highest susceptibility to the three pyrethroids tested recording the lowest LC_{50} values followed by KNL and GNT strains. Correspondingly, SKL strain was highly dose-responsive to cypermethrin and decamethrin as evidenced in higher slope values (regression coefficients). The least susceptible was GNT strain recording the highest LC_{50} values as well as comparatively lower dose-dependent response (slopes). Highest susceptibility of SKL strain to the synthetic pyrethroids is due to the fact that the insect is not exposed to insecticidal pressure in Srikakulam region as in Guntur where commercial crops like cotton, chillies, tobacco etc. receive over doses of insecticides.

TABLE 1. Probit analysis of dosage-mortality response of third instar larvae of three strains of *H. armigera* to certain synthetic pyrethroids

Insecticide	Strain of test larvae	Chi² (3)	Regression Equation	LC_{50}	Fiducial limits 95%
Cypermethrin	GNT	0.2217	Y = 3.0949 + 0.0899x	0.0131	0.0041 — 0.0419
	KNL	0.1343	Y = 3.3211 + 0.8947x	0.0073	0.0030 — 0.0775
	SKL	3.3353	Y = 3.4346 + 1.8275x	0.0070	0.0002 — 0.0011
decamethrin	GNT	0.6347	Y = 2.8698 + 1.2716x	0.0047	0.0047 — 0.0082
	KNL	0.4210	Y = 3.6220 + 0.9377x	0.0029	0.0014 — 0.0062
	SKL	1.7459	Y = 3.6229 + 1.7493x	0.0006	0.0002 — 0.0009
fenvalerate	GNT	0.0490	Y = 2.2565 + 1.6485x	0.0046	0.0029 — 0.0078
	KNL	5.6318	Y = 0.4930 + 3.0320x	0.0032	0.0025 — 0.0041
	SKL	2.1829	Y = 3.8898 + 1.5014x	0.0005	0.0009 — 0.001

Strain of larvae — GNT (Guntur); KNL (Kurnool) & SKL (Srikakulam).

For the computation of resistance index values, the SKL strain was taken as standard and the development of resistance in GNT and KNL strains was assessed in comparison with the most susceptible SKL strain (Table 2). The data revealed that GNT strain of *H. armigera* was 18.71, 7.83 and 9.20 times resistant and KNL strain 10.45, 4.83 and 6.40 times resistant to cypermethrin, decamethrin and fenvalerate respectively. In the recent past, Mc CAFFERY *et al.* (1989) observed high levels of resistance to cypermethrin and fenvalerate in *H. armigera* in certain locations in Andhra Pradesh. Similar obesrvations were made with cypermethrin by DHINGRA *et al.* (1988) and ANONYMOUS (1988). In the light of the present finding, the concept of insecticide-resistance management is worth considering to utilize effectively the insecticide component particularly synthetic pyrethroids, in IPM strategies.

TABLE 2. Resistance levels in Guntur and Kurnool strains of *H. armigera* in comparison with Srikakulam strain

Insecticide	Resistance Index	
	GNT strain (LC_{50} of GNT/ LC_{50} of SKL)	KNL strain (LC_{50} of KNL/ LC_{50} of SKL)
Cypermethrin	18.71	10.45
decamethrin	7.83	4.83
fenevalerate	9.2	6.40

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Entomon 1991 Vol. 16 No. 3 pp. 237 to 239

BRIEF COMMUNICATION

OVICIDAL ACTION OF SYNTHETIC PYRETHROIDS ON THE EGGS OF BIHAR HAIRY CATERPILLAR, *SPILOSOMA OBLIQUA* (WALKER) AND SESAMUM SPHINX, *ACHERONTIA STYX* (WEST WOOD)

S. C. Goel & Sanjay Kumar[1]
P. G. Department of Zoology, Sanatan Dharm College, Muzaffarnagar, India 251 001

(*Received* 12 *August* 1990)

The ovicidal action of six insecticides revealed that cypermethrin, deltamethrin, fenpropathrin, fenvalerate and fluvalinate were poorly ovicidal but quite effective to newly hatched larvae. Quinalphos, however, showed ovicidal action. These insecticides, moreover, checked the survival of progeny.

(*Key words*: cypermethrin, deltamethrin, fenpropathrin, fenvalerate, fluvalinate, quinalphos, *Spilosoma obliqua*, *Acherontia styx*, ovicidal action)

Insecticides with ovicidal action are of great imortance as they also limit the next progeny. Sesamum (*Sesamum indicum* L.) a rich oil yielding crop of India, suffers many insect pests. *Spilosoma obliqua* (Wlk.) and *Acherontia styx* (Westw.) are capable of denuding the crop, resulting in heavy losses to the growers. Ovicidal action of insecticides of different classes have been evaluated in the laboratory against a wide range of insect species (Tysowsky & Gallo, 1977; Rawat *et al.*, 1981; Ho & Goh, 1984; Singh & Sarup, 1985; Vekaria & Vyas, 1985; Nagia *et al.*, 1989; Patel *et al.*, 1989). However, limited work has been done in the field (Jena *et al.*, 1985; Ghattas *et al.*, 1987). Therefore, a study of ovicidal action of synthetic pyrethroids and quinalphos against the eggs of *S. obliqua* and *A. styx* has been made.

A field experiment in randomised block design, with triplicate treatments was conducted at S. D. College campus during 1989. The individual plot size was 4 m × 5 m. The plants were spaced 15 cm within the rows, which were 30 cm apart. Three foliar sprays of cypermethrin (Ripcord 10 EC) @ 60 g ai/ha, deltamethrin (Decis 2.8 EC) @ 15 g ai/ha, fenpropathrin (Danitol 10 EC) @ 100 g ai/ha, fenvalerate (Sumicidin 20 EC) @ 100 g ai/ha, fluvalinate (Mavrik 25 EC) @ 100 g ai/ha and quinalphos (Suquin 25 EC) @ 500 g ai/ha were given to the crop at 15 days interval. Control plots were sprayed with water only. Before each spray, leaves containing eggs of *S. obliqua* and *A. styx* were tagged. Plots in which no eggs of *S. obliqua* were found, leaves along with eggs plucked from the bulk crop were hung down and tied in such plots with the plants. After 2 hours of each spray, these leaves containing eggs were removed from the plants and brought to the laboratory in glass jars (10×15 cm). Twenty eggs per replicate taken from separate leaves were kept in Petri dishes provided with moist tissue paper at the base to keep leaves turgid and observed upto 6 days of spray. Further observations revealed no more hatching of eggs and mortality of newly hatched larvae.

[1]Central Insecticides Laboratory, Directorate of Plant Protection, Quarantine and Storage, NH-IV, Faridabad 121 001, India.

Larvae half way out from the egg shell were considered as hatched. Data were subjected to angular transformation before statistical analysis.

During the period of study the prevailing mean maximum and minimum temperatures were 35.83±0.70°C and 24.63±0.26°C respectively. Mean maximum and minimum RH were 90.10±1.09 % and 69.03± 2.75% respectively.

Results summarised in Table 1 reveal that all the insecticides were significantly superior over untreated control. Synthetic pyrethroids were less toxic to eggs in comparison to quinalphos, while most toxic to newly hatched larvae for both the insects. Most of the larvae died soon after hatching. Deltamethrin restricted cent percent survival of progeny, while remaining pyrethroids allowed upto 11.67 percent.

An ovicidal action depends on the penetration ability of different groups of insecticides through the egg shell, as observed in the case of organochlorines, organophosphaates and carbamates, where the larva died before hatching even without attempting to cut the chorion of the egg. In synthetic pyrethroids the larvae died while attempting to cut the chorion of the egg and sometimes soon after hatching in the present observation. Neonate larvae also died after crawling and feeding for a while on the treated leaves.

TABLE 1. Ovicidal action of synthetic pyrethroids and quinalphos against *Spilosoma obliqua* (Wlk.) and *Acherontia styx* (Westw.) (Mean of three sprays).

Insecticide	Dose g a i /ha	*S. olbiqua*			*A. styx*		
		Percent mortality of eggs	Percent mortality of newly hatched larvae	Percent survival of progeny	Percent mortality of eggs	Percent mortality of newly hatched larvae	Percent survival of progeny
cypermethrin	60	45.00 (42.41)	100.00 (90.00)	0 (4.05)	38.33 (38.49)	94.44 (82.10)	3.33 (9.00)
deltamethrin	15	48.33 (44.31)	100.00 (90.00)	0 (4.05)	43.33 (41.43)	100.00 (90.00)	0 (4.05)
fenpropathrin	100	38.33 (38.52)	91.38 (76.53)	5.00 (12.17)	35.00 (36.54)	84.34 (67.66)	10.00 (18.55)
fenvalerate	100	40.00 (39.44)	95.24 (82.73)	3.33 (9.00)	31.67 (34.46)	90.63 (76.13)	6.67 (13.60)
fluvalinate	100	41.67 (40.47)	93.94 (81.71)	3.33 (9.00)	26.67 (31.27)	84.52 (67.65)	11.67 (19.97)
quinalphos	500	71.67 (58.59)	59.72 (50.96)	11.67 (19.97)	56.67 (49.23)	41.11 (40.13)	25.00 (30.26)
control (water spray)		3.33 (9.00)	0 (4.05)	96.67 (84.02)	5.00 (12.17)	0 (4.05)	95.00 (79.93)
S Em ±		(4.39)	(7.36)	(5.66)	(4.57)	(6.21)	(5.51)
C D ($P = 0.01$)		(13.41)	(22.48)	(17.29)	(13.96)	(18.97)	(16.83)

Figures in parantheses are arc sin $\sqrt{P + 0.5}$ values

Laboratory based studies of SINGH & SARUP (1985) VEKARIA & VYAS (1985) revealed that synthetic pyrethroids were as toxic as quinalphos against the eggs of *Chilo partellus* (Swin.), *Heliothis armigera* (Hb.). On the other hand RAWAT *et al.* (1981) and PATEL *et al.* (1989) described synthetic pyrethroids significantly superior to quinalphos against *Clavigralla gibbosa* (Spin.). In the present study quinalphos remained significantly superior over synthetic pyrethroids in the field against the eggs of *S. obliqua* and *A. styx*. NAGIA *et al.* (1989) have also reported endosulfan, monocrotophos, methyl parathion and cypermethrin as effective ovicidal insecticides against *S. obliqua* in laboratory experiments. GOEL & KUMAR (1990) also endorsed that synthetic pyrethroids found vitally toxic against the larvae of *S. obliqua* and *A. styx* on sesamum.

It is, therefore, concluded that quinalphos is fairly good ovicide, and less toxic to newly hatched larvae. The synthetic pyrethroids although proved less ovicidal, but are quite effective against newly hatched larvae of *S. obliqua* and *A. styx*. As such the synthetic pyrethroids were able to check the growth of the next progeny, would further be quite useful in achieving significant reduction of the pest population before it turns into an epidemic form.

ACKNOWLEDGEMENTS

Authors are grateful to Dr. L. N. MITTAL, Principal, S. D. College, for providing necessary facilities, and to Dr. R.L. Rajak, Plant Protection Adviser (Government of India) for encouragement. Thanks are also due to M/s NOCIL, Bombay; M/s Hoechst India Ltd., Bombay; M/s Rallis India Ltd., Banglore and Thane; M/s Sandoz India Ltd., Bombay and M/s Sudarshan Chemicals & Industries Ltd., Pune for providing the insecticide samples used in the present study.

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Entomon 1991 Vol. 16 No. 3 pp. 241 to 244

BRIEF COMMUNICATION

EFFICACY OF SELECTED INSECTICIDES AGAINST MUSTARD APHID, *LIPAPHIS ERYSIRNI* KALT (HOMOPTERA : APHIDIDAE)

K. M. SRIVASTAVA, SANTOSH KUMAR SRIVASTAVA & DHARAM RAJ SINGH
Department of Entomology
C. S. Azad University of Agriculture and Technology, Kanpur, India 208 002

(*Received* 23 *September* 1990)

Six selected insecticides viz., phosphamidon, methamedophos, monocrotophos, primicarb, formothion and phenthoate (each at 0.025% concentration) were evaluated for their relative efficacy against mustard aphid *Lipaphis erysimi* Kalt. during 198–1985 and 1985–1986 in field condition at C. S. Azad University Research Farm, Kalyanpur, Kanpur. Monocrotophos gave maximum yield followed by phosphamidon. Maximum cost benefit ratio was recorded in phosphamidon 1:55.39 for the first year and 1:45.52 for the second year. Therefore phosphamidon may be recommended as one of the cheapest insecticides to combat mustard aphid *Lipaphis erysimi* Kalt.

(*Key words*: *Lipaphis erysimi*, CB ratio, insecticides)

Lipaphis erysimi Kalt, is a limiting factor in the cultivation of rapeseed and mustard. The colonies of mustard aphids feed on new shoots, inflorescence and the under side of leaves. SIDHU & SINGH (1984) reported its biology in detail. BUTANI (1974) reported that at least two sprayings should be given either with 0.02% phosphamidon or 0.02% methyl-0-demeton. To control the mustard aphid different insecticides have been suggested by various workers viz., PRADHAN *et al.* (1960); ROUT & PANI (1968); KRISHNAIAH & RATNLAL (1975); MUKHOPADHYAY (1979) and BRAR & SANDHU (1981). Reduction in the losses caused by pests, by timely and effective control measures will considerably add to our food production in the country. Therefore, it is necessary to develop an effective economical control measure against mustard aphid.

The efficacy of selected insecticides (vide Tables 1 and 2) was tested in two crop seasons during Rabi 1984-1985 and 1985-1986 at University Research Farm, Kalyanpur, Kanpur. The insecticides were tested in 3 replications in a randomized block design using seed of variety 'Varuna'. Foliar sprays were given and aphid counts on five randomly selected 5 cm. inflorescence shoots were recorded one day before and one, three, seven and fifteen days after the foliar treatment. Ultimately yield data were also recorded for the computation of cost benefit ratio of the various insecticides. During 1984–1985 only one foliar spraying was given because there was no aphid population after 15 days first spraying while during 1985–1986 two foliar sprayings were given due to the presence of aphid population.

The aphid population data before spraying indicate non-significant differences during both the year among the various lots (vide Tables 1 and 2). The data of 1 day after spray gave an indication of better performance of treatments over control during both the year. Methamedophos gave the lowest incidence (15.86) as compared to the highest incidence (143.0) in control during 1984-1985. While during 1985-1986 lowest incidence (7.48) was recorded in monocrotophos treated plot as compared to the highest incidence (15.15) in control after 1 day to

TABLE 1. Efficacy of selected insecticides against mustard aphid, *Lipaphis erysimi* Kalt. during 1984–1985.

S. no.	Insecticides	Population of aphid					Yield Q/ha.	Cost benefit ratio
		BS	1 DAS	3 DAS	7 DAS	15 DAS		
1.	phosphamidon 0.025%	134.66	46.13	18.33	9.80	9.33	6.40	1:43.31
2.	methamedophos 0.025%	206.71	15.86	19.86	14.33	16.00	3.73	—
3.	monocrotophos 0.025%	202.33	26.76	11.46	7.33	5.00	7.20	1:26.26
4.	primicarb 0.025%	198.33	27.13	13.60	9.66	13.33	4.13	
5.	formothion 0.025%	176.66	37.73	14.33	38.00	48.33	3.33	1:14.85
6.	phenthoate 0.025%	207.66	48.13	20.00	65.66	50.00	3.20	1:17.61
7.	Control	197.33	143.00	193.33	806.00	800.00	0.73	
	C D 5%	N. S.	66.389	60.242	49.029	71.614	0.1811	
	C V	10.5	63.3	81.50	20.29	29.97	19.80	

Design– R.B.D., Plot size : 6×2.5 metre, variety-Varuna.
Replication–3, Sowing date–16.11.1984 spraying date 23.1.1985.
N S – Non significant, DAS–Days after spraying.
B S – Before spraying.

Note: The cost of methamedophos and primicarb is not known.

first sray, while 1 day after second spray the same trend was observed and monocrotophos gave the lowest incidence (0.83) as compared to the higest incidence (20.72) in control. At 3rd day after spraying during first year better result was observed in monocrotophos, primicarb and formothion having aphid population 11.46,13.60 and 14.33 respectively, while during second year after first spraying monocrotophos, phosphamiddon, primicarb and chlorpyrifos gave better results having aphid population 0.96, 1.13, 1.37 and 1.45 respectively. After second spraying better results was noticed in monocrotophos, formothion, phosphamidon, primicarb and cholrpyrifos having aphid population 0.90, 1.16, 1.21 and 2.78 respectively. At 7th day and 15 the day after Ist spraying during both the years monocrotophos and phosphamidon gave best results, while after 7th day and 15th day after 2nd sprayng during second year although monocrotophos was superior but primicarb stand on the place in comparison to phospamidon.

During 1984–1985 phosphamidon and monocrotophos gave highest yield 640 kg/ha and 720 kg/ha and maximum cost benefit ratio 1:43.31 and 1:26.26 respectively. While during 1985–1986 highest yield was recorded in monocrotophos (689 kg/ha) followed by phosphamidon (605 kg/ha). The maximum cost benefit ratio was found in phosphamidon and monocrotophos i.e., 1:55.39 and 1:45.52 respectively.

On the basis of yield data during 1984–1985 no significant difference was observed in phenthoate and formothion, they were equally effective but superior over control, while other insecticides were significantly superior among themselves. During 1985–

TABLE 2. Efficacy of selected insecticides against mustard aphid, *Lipaphis erysimi* Kalt. during 1985–1986.

S. no.	Insecticides	Population of aphid										Yield Q/ha.	Cost benefit ratio
		BS	1DAFS	3DAFS	7DAFS	15DAFS	B.S.	1DASS	3DASS	7DASS	15DASS		
1.	phosphamidon 0.025%	155.00	35.93	1.13	2.80	5.83	5.49	1.27	1.16	2.73	2.11	6.05	1:55.39
2.	methamedophos 0.025%	164.00	42.61	1.72	3.24	10.63	8.89	5.31	4.63	6.65	3.26	3.28	—
3.	monocrotophos 0.025%	140.67	7.48	0.96	0.71	1.45	2.38	0.83	0.90	0.79	1.29	6.89	1:45.52
4.	primicarb 0.025%	137.00	15.75	1.37	3.99	7.28	5.07	1.16	1.21	1.85	1.84	3.95	—
5.	formation 0.025%	190.00	20.63	3.36	3.48	9.95	7.43	2.57	1.09	1.91	3.23	2.89	1:18.15
6.	Phenthoate 0.025%	195.00	14.62	1.85	3.57	9.17	8.81	5.05	5.58	7.79	3.17	3.00	1:23.60
7.	Chlorphyrifos 0.03%	179.00	16.66	1.45	2.53	5.21	5.33	2.63	2.78	4.86	2.10	3.25	1:15.60
8.	Control	146.00	151.75	12.76	15.84	17.82	18.46	20.72	14.65	12.52	7.89	0.63	—
	C D 5%	N.S.	53.44	2.16	4.35	8.76	3.59	3.21	2.71	3.60	1.59	0.05	
	C V	28.7	81.54	40.15	54.9	59.46	26.56	37.10	38.78	42.08	29.22	13.35	

Design- R. B. D., plot size – 4×1.5 metre, varety-Varuna.
Replication – 3, sowing date 7–11–1985.
First spraying 4–1–86; DAFS – Days after First spraying.
Second spraying 23.1.86; DASS – Days after second spraying.

Note: The cost of methamedophos and primicarb is not known.

1986 all the insecticides were significantly superior among themselves and finally superior over control at 5% level of significance.

From above it is amply clear that although monocrotphos gave maximum yield in both the year followed by phosphamidon but maximum cost benefit ratio was found in phosphamidon. Therefore, phosphamidon can be recommended to the farmers and extension workers in order to combat with mustard aphid *Lipaphis erysimi* Kalt.

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Entomon 1991 Vol. 16 No. 3 pp. 245 to 246

BRIEF COMMUNICATION

OCCURRENCE OF *HELOPELTIS THEIVORA* WATERHOUSE (MIRIDAE : HEMIPTERA) AS A PEST OF INDIAN LONG PEPPER *PIPER LONGUM* LINN.

C. C. ABRAHAM
College of Horticulture, Vellanikkara, Trichur, Kerala, India 680 654

(*Received* 30 *June* 1990)

***Helopeltis theivora* Waterhouse was recorded to cause severe damage to the tender foliage of the Indian long pepper *Piper longum*. Application of neem kernel suspension at two percent, reduced the extent of damage by 70 percent.**

(*Key words*: tea mosquito bug, *Helopeltis theivora*, Indian long pepper, *Piper longum*, neem kernel suspension)

The dry spikes and roots of the Indian long pepper *Piper longum* ("Thippali") have numerous medicinal properties and are extensively used against diseases of the tract and as a carminative.

Growing long pepper plant as a floor crop in the coconut plantations is found to be a very profitable venture. There is a heavy demand for the long pepper spikes for the preparation of several ayurvedic drugs. At present, the requirements are partially met by the produce collected from the wild plants occurring in the forest of Assam, West Bengal, Uttar Pradesh and Maharashtra and mainly through imports from Nepal, Malaysia and Singapore.

In the Kanjoor area near Kalady, Ernakulam District, Kerala, the long pepper crop is very successfully cultivated in an area of about four hectares. During September-October 1989, the crop grown in this plantation was found to be severely infested by the adults and nymphs of the tea mosquito bug *Helopeltis theivora* Waterhouse. This is the first record of the insect on *P. longum*. Large number of these insects were found on the tender foliage in the morning hours. The feeding habits of the adults and nymphs were similar. Around the feeding punctures truncated water soaked lesions develop within 48 hours. The affected tissues in the lesions dry up and turn brownish-black. Later, necrotic tissues are blown off leaving shot holes on the lamina (Figs. 1 and 2). The shoots and petioles were not preferred for feeding. Among the nymphs, the fourth and fifth instar individuals were found to feed more actively than the early instars.

The populations of the insect were found to decrease progressively after November and reached very low levels in the summer months of March–April.

A preliminary field trial was conducted in an area of 0.25 ha to assess the efficiency of the neem kernel suspension at 2 percent, applied as high volume spray, aginst the pest stages. The kernel suspension was applied using a rocking sprayer at the rate of 500 litres/ha. The untreated plot of equal area was kept as the control plot. Observations on the intensity of damage in terms of the number of lesions on the foliage at 15 days after spraying showed a definite trend of reduction of damage due to the treatment, to the extent of 70 percent as compared to control.

Figs. 1 and 2. Damage caused to tender leaves of *Piper longum* by *Helopeltis theivora*.

Helopeltis theivora has been recorded as a serious pest of tea in northern India and in Kerala State (CRANHAM, 1966). DAS (1965) recorded *Melastoma malabathricum* (wild rhododendron), *Maesa ramentacea, Eurya acuminata, Jasminum scandens* and *Mikania micrantha* as alternate hosts of *H. theivora*. AMBIKA & ABRAHAM (1983) recorded this insect for the first time as pest of cashew in Kerala and provided a tentative key based on morphological characters of the males. The male genitalia of *H. theivora* agreed with the descriptions given by PATHAK (1969). DEVASAHAYAM *et al.* (1986) reported the occurrence of *H. antonii* Signoret infesting tender shoots and leaves of young black pepper vines in Calicut District.

ACKNOWLEDGEMENT

The author is grateful to Dr. USHA RAMAKRISHNAN, Principal Scientist, Division of Entomology, IARI, New Delhi–12 for the valuable help in establishing the taxonomic identity through genetalic studies. The help rendered by Mr. P. D. VARGHESE, Kanjoor, in making field collections of the insect and in conducting the field trials in his garden is gratefully acknowledged.

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Entomon 1991 Vol. 16 No. 3 pp. 247

REPORTS AND NEW RECORDS

FIRST RECORD OF LEAFLET GALLS ON *REIDIA LONGIFOLIA* GAMBLE INDUCED BY A PSYLLID

K. THENMOZHI, C. KANDASAMY & B. V. DAVID
Fredrick Institute of Plant Protection & Toxicology, Padappai, India 601 301

(*Received* 12 *August* 1990)

A psyllid *Peripsyllopsis ramakrishna* (Enderlein) has been noticed to cause galls on leaflets of *Reidia longifolia* Gamble in Thimbam forest, Karnataka.

(*Key words*: *Peripsyllopsis*, *Reidia*, psyllid)

Psyllids are known to induce galls on leaves, inflorescence, and shoots of dicot plants. Fifty three species of psyllids have been reported to form galls in the Oriental region, accounting for 37% of the total Oriental psyllid fauna (MATHUR, 1975). During a survey in 1985 galls from leaflets of *Reidia longifolia* Gamble (Euphorbiaceae) were collected in Timbam forest, Karnataka. The gall making psyllid was identified as *Peripsyllopsis ramakrishni* (Enderlein).

The infested leaflets show inward rolling of the lamina from the margin towards the midrib. The rolling may be partial, restricted to the basal half of the leaflets or sometimes complete. The galls measuring 3–5 mm are noticed both on the tender as well as mature leaflets appearing yellow in colour. An infested twig generally contains 8–25 galls.

Psyllid nymphs of all stages occur simultaneously inside the gall chamber. However, the first and second instar nymphs are noticed in galls on tender leaves. Generally 8–10 nymphs occur in a single gall. The nymphs surrounded by a sticky white waxy secretion are pale green and sluggish. The fifth instar nymphs are often seen moving out of the gall which indicates the possibilities of adult emergence outside the gall chamber. During the month of June, 1985, when the survey was made, the population of fifth instar nymphs and adults were found to be higher than that of other stages. Observations indicated the sex ratio of male and female as 2:3.

The present report of gall induction by the psyllid *P. ramakrishni* (Enderlein) is a new record. This species has earlier been reported to cause galls on leaves of *Chloroxylon sweieteria* DC. (Rutaceae) (MANI, 1973). Psyllids, especially the gall forming species are highly host specific and it is interesting to note that this species occurs on hosts belonging to Euphorbiaceae and Rutaceae.

Thanks are due to Dr. J. H. MARTIN, British Museum (Natural History), London for identifying the psyllid, and to the Botanical Survey of India, Southern Circle, Coimbatore for identifying the host plant. The financial assistance of the CSIR, New Delhi is gratefully acknowledged.

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Entomon 1991 Vol. 16 No. 3 pp. 248

REPORTS AND NEW RECORDS

NEW RECORD OF *KUSHALA MACULATA* DWAR. (HOMOPTERA : CICADELLIDAE) ON COTTON FROM SOUTH INDIA*

S. P. SINGH & S. K. JALALI
Biological Control Centre, National Centre for Integrated Pest Management, Hebbal Agricultural Farm Post, Bangalore, India 560 024

***Kushala maculata* Dwar. was recorded for the first time infesting cotton in South India.**

(*Key words*: *Kushala maculata*, cotton, new record)

Survey to identify natural enemies of leaf hoppers in India was carried out in and around Bangalore. On cotton two species of leafhoppers recorded from Hebbal area were *Amrasca biguttula biguttula* (Ishida) and *Kushala maculata* Dwar. The latter was recorded for the first time on cotton in India. Population density of *K. maculata* nymphs and adults was 0.61 and 0.93 per leaf, respectively compared to 0.83 and 0.18 of *A. biguttula biguttula* during September–October, 1989.

K. maculata had been earlier recorded on *Celtis australis* Linn. (Hackberry) and *Pyrus pashia* Ham. Mchal. in North-Western India. (Sohi, 1988). Its occurrence on cotton and at higher levels than *A. biguttula biguttula* could possibly be an indication of its potential to assume pest status.

*Contribution No. 15005 of Biological Control Centre, NCIPM, Bangalore.

ACKNOWLEDGEMENTS

The authors are thankful to USAID for financial assistance, to Dr. C. A. VIRAKTAMATH, Prof. Entomology, University of Agricultural Sciences, Bangalore for identifying the leaf hoppers and to Ms. S. K. Rajeshwari for necessary help.

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Entomon 1991 Vol. 16 No. 3 pp. 249

REPORTS AND NEW RECORDS

OBSERVATIONS ON THE PEST COMPLEX OF *BALANITES AEGYPTIACA* (L) DELILE IN THE ARID ZONES OF INDIA

M. P. SINGH
Central Arid Zone Research Institute, Jodhpur, India 342 003

(*Received* 23 *September* 1990)

The pyralid, *Ectomyelosis ceratoniae* Zeller infests the pulp, and a *Eupsoropsis* sp. a noctuid, infests the seed kernel, of *Balanites aegyptiaca*.

(*Key words*: *Balanites*, pest complex)

Balanites aegyptiaca (L) Eelile, a natural growing bush in the arid and semi-arid regions of Western Rajasthan, locally known as 'Hingota', has recently been recognised to be a plant of economic importance. The seed kernels of the fruits contain 40–60 percent oil and 0.8 percent diosgenin, a precursor for steroid drugs used as contraceptives. The fruits of this plant suffer heavy insect attack, limiting the availability of the obtainable useful products.

Two Lepidopterous insects were found causing injury– one to the fruit pulp and the other to the seed kernel. The one infesting the pulp was identified as *Ectomyelois ceratoniae* Zeller, a pyralid. The insect feeding on seed kernel was identified to be *Eupsoropsis* sp., a noctuid. The specimens were very similar, but not identical to the African racefly *E. robertsi* Berio.

The pyralid larva feeds on the pericarp rich in reducing sugars and sapogenin, and lowers the diosgenin content of the fruits. The noctuid larva feeds on the seed kernel, generally one larva is found in the infested seed. The larva cuts an exit hole through the stone, pulp and epicarp, while the fruit is still immature. It pupates in the seed itself. The moth emerging from the pupa finds its way out through the exit hole.

The noctuid attack on seed kernel of *Balanites* paves the way for secondary infestation of kernel by tenebrionid and dermestid beetles (to be identified) which enter through the exit hole. The grubs and beetles feed on the left over seed kernel, thus destroying the entire kernel from which oil and diosgenin could be obtained.

A search into literature showed no reference of infestation on *B. aegptiaca* by these insects and as such the present information constitutes a new host and pest record.

The author is grateful to Drs. J.D. HOLLOWAY and J. D. BRADLEY of Commonwealth Institute of Entomology, London, for identification of the Lepidopterans.

ANNOUNCEMENTS

V NATIONAL SYMPOSIUM ON APHIDOLOGY

The V National Symposium on Aphidology which was scheduled for October 28–31, 1991, is postponed to October/November 1992. Further details may be had from Dr. K. C. Devaraj Urs, Organising Secretary, National Symposium on Aphidology, Department of Entomology, Agricultural College, GKVK, Bangalore 560065.

DROSOPHILA STOCK CENTRE

A *Drosophila Stock Centre* is being established at the Department of Studies in Zoology, University of Mysore, Manasagangotri, Mysore-570006 with the financial assistance of the Department of Biotechnology, Government of India. The proposed centre will maintain and supply free of cost the genetic stocks of *Drosophila melanogaster* and the strains of other available species, required for routine teaching and research purposes. Therefore, to establish the germplasm, the Centre requests contributions of *Drosophila* stocks from different laboratories. For further information, interested persons may contact Dr. H. A. RANGANATH, Principal Investigator of the Stock Centre.

CORRIGENDUM

ENTOMON, 1990, Vol. 15, No. 3 & 4, Page 281–282, Paper entitled: A new *Eryngiopus* Summers (Acari: Stigmaidae) from India, by S. K. GUPTA & H. DAVID. The new species was collected in association with *Melanaspis glomerata* Green and not *Saccharicoccus sacchari* (Cockerell) as appeared in the paper. Authors deeply regret this inadvertent error.

AUTHOR INDEX

Abraham, C. C., 245
Balaraman, K., 213
Bhagavan, S., 167
Chidambaram, P., 229
David, B. V., 247
David, H., 223
Easwaramoorthy, S., 223
Gadagkar, R., 167
Gangwar, S. K., 209
Goel, S. C., 237
Hayat, M., 179, 183
Jalali, S. K., 248
Kalia, S., 193
Kandasamy, C., 247
Kaushal, B. R., 193
Kumar, S., 237
Kuppusamy, M., 213
Malpe, R., 167
Mohanasundaram, M., 187
Murthy, M.M.K., 233
Natarajan, K., 229
Paul, D. C., 203
Prasad, V. D., 233
Rajendran, G., 213
Rao, G. S., 203
Reddy, G.P.V., 233
Roychaudhury, N., 203
Sabasean, S., 213
Satyavani, P., 233
Shanmugasudaram, M., 223
Singh, D. R., 241
Singh, M. P., 249
Singh, S. P., 248
Somasundaram, P., 209
Srivastava, K. M., 241
Srivastava, S. K., 241
Sundaramoorthy, V. T., 229
Swaminathan, R., 217
Thenmozhi, K. 247
Vasuki, V., 175
Verma, S. K., 217
Vinutha, C., 167

Reg. No. R. N. 29386/76

(*Continued from cover page* 1)

Evaluation of a *Bacillus sphaericus* formulation, Spherifix™ for the control of mansonioides larvae: G. RAJENDRAN, S. SABESAN, M. KUPPUSAMY and K. BALARAMAN 213

Studies on the incidence of date palm scale, *Parlatoria blanchardi* (Targ.) in western Rajasthan: R. SWAMINATHAN and S. K. VERMA 217

Laboratory technique for mass multiplication of pink borer, *Sesamia inferens* Walker (Noctuidae) : (Lepidoptera): S. EASWARAMOORTHY, H. DAVID and M. SHANMUGASUNDARAM 223

Usefulness of fish oil rosin soap in the management of whitefly and other sap-feeding insects of cotton: K. NATARAJAN, V. T. SUNDARAMOORTHY and P. CHIDAMBARAM 229

Comparative assessment of pyrethroid resistance in certain populations of *Heliothis armigera* Hubn. in Andhra Pradesh: G. P. V. REDDY, V. DEVA PRASAD, P. SATYAVANI and M. M. K. MURTHY 233

BRIEF COMMUNICATIONS

Ovicidal action of synthetic pyrethroids on the eggs of Bihar hairy caterpillar, *Spilosoma obliqua* (Walker) and Sesamum sphinx, *Acherontia styx* (Westwood) S. C. GOEL and SANJAY KUMAR 237

Efficacy of selected insecticides against mustard aphid, *Lipaphis erysimi* Kalt (Homoptera: Aphididae): K. M. SRIVASTAVA, SANTHOSH KUMAR SRIVASTAVA and DHARAM RAJ SINGH 241

Occurrence of *Helopeltis theivora* Waterhouse (Miridae: Hemiptera) as a pest of Indian long pepper *Piper longum* Linn: C. C. ABRAHAM 245

REPORTS AND NEW RECORDS

First record of leaflet galls on *Reidia longifolia* Gamble induced by a psyllid: K. THENMOZHI, C. KANDASAMY and B. V. DAVID 247

New record of *Kushala maculata* Dwar. (Homoptera: Cicadellidae) on cotton from South India: S. P. SINGH and S. K. JALALI 248

Observations on the pest complex of *Balanites aegyptiaca* (L) Delile in the arid zones of India: M. P. SINGH 249

ANNOUNCEMENTS 250

V NATIONAL SYMPOSIUM ON APHIDOLOGY 250

CORRIGENDUM 250

Published by V. K. K. Prabhu and Printed at St. Joseph's Press, Trivandrum 695014
for the Association for Advancement of Entomology